VOL. 13, NO. 2 June, 1938

THE QUARTERLY REVIEW
of BIOLOGY

DIURNAL RHYTHMS

By
JOHN H. WELSH
Biological Laboratories, Harvard University

REGULARLY recurring changes in the physical environment, such as are due to the seasons, the lunar month, the tides, and day and night, have resulted in the establishment of biological cycles. These are evident in the tendency for animals to migrate or hibernate, as reproductive cycles, and as tidal and daily rhythms of various kinds. In the normal environment these physiological cycles are kept in operation by the recurring external events, but in certain instances it is evident that they have been so well established within the organism that they may persist in the absence of the normal external stimuli. Many daily rhythms, normally kept in operation by day and night, are known to persist when the plant or animal is maintained under constant external conditions. It is with various types of such persisting diurnal rhythms in animals that we shall be concerned in this review.

The term "diurnal rhythm" is somewhat misleading for, although it is commonly used to designate a 24-hour cycle or something recurring each day, it is occasionally employed to distinguish a phenomenon which is evident during the day as opposed to one which is evident during the night, a "nocturnal rhythm". If we persist in speaking of diurnal rhythms we must be cautious in employing the word "diurnal" to designate that phase of the rhythm or cycle which occurs during the day. For example if one is discussing the behavior of an animal which is normally active during the day and quiescent at night, it would be less confusing to speak of the active period as the "day-phase" than to say that the animal has a "diurnal activity rhythm". Such terms as nocturnal, auroral, diurnal, and vesperal have been suggested to describe the active periods of different animals by Carpenter (1932) and others. At times such terms are convenient but the other common meaning of the word diurnal, "recurring every day", must be kept in mind. It would doubtless save much further confusion if we applied the term "24-hour cycles" to variable phenomena in plants and animals which have a period

BOSTON UNIVERSITY
COLLEGE OF LIBERAL ARTS
LIBRARY

of twenty-four hours, but since the term "diurnal rhythm" is in common use it will be employed in this review and considered to have the same meaning as "24-hour cycle".

Daylight and darkness have distinctly different effects on many biological processes, as for example on the rate of photosynthesis in plants. The process of photosynthesis obviously cannot continue in constant darkness. There are doubtless many such phenomena associated with day or night, which are rhythmical under natural conditions and operate in 24-hour cycles, but which are completely dependent on changes in the external environment. On the other hand, as an example from the plant kingdom, the nightly folding of the leaves of the *Mimosa* or "sensitive plant" persists for days when the plant is kept in a constant environment. Among animals, light production, color change, retinal changes, metabolic and general activity rhythms may persist for long periods of time in the absence of changes in the external environment, on which they are normally dependent. Numerous studies of persisting diurnal rhythms in animals have been made and various suggestions have been offered to explain the persistence, but in no single instance has there been a satisfactory experimental demonstration of the complete chain of events which keeps the internal rhythm or cycle operating. In the sex cycle the demonstration of the interdependence of the pituitary and gonads and the cyclical changes in the pituitary helps greatly in our understanding of this complex process. Nothing as definite as this is known about diurnal rhythms. It seems desirable, however, to bring together the results of various investigations and the suggestions offered to explain the findings.

LIGHT PRODUCTION

Most animals which produce light, other than those of the deep sea, do so only at night. Bouvier (1922) discusses this periodic luminescence and other "vital rhythms" in a most stimulating manner. He cites the work of Dubois on the West Indian elaterid, *Pyrophorus noctilucus*, or "cucujo". This was one of the first demonstrations of the persistence of rhythms. Dubois kept these insects in constant darkness, at a nearly constant temperature, and found that they became active every evening at the same hour and began to produce light. Buck (1937) finds that males of the firefly, *Photinus pyralis*, ordinarily flash in the evening between 7 and 9 o'clock. Kept in continuous darkness they do not flash. If after being in darkness they are illuminated with light of a low intensity they flash provided they have been in the dark for 24, 48, 72, or 96 hours, but they fail to flash if they have been in the dark for 12, 36, 60, or 84 hours. When males are kept in darkness and exposed to weak light before the end of 24 hours they do not flash until the sum of the time spent in darkness and the time spent in weak light is equal approximately to 24 hours. It is clear that there exists in this firefly a diurnal periodicity which is manifested by periods of flashing which recur at 24-hour intervals and which persist for at least 4 days in the uniform environment of the darkroom.

Certain phosphorescent copepods were kept in constant darkness for as long as 12 days by Moore (1919). They showed increased activity and light production between 6 P.M. and 5 to 6 A.M., but no light was produced during the day. Moore offered the following explanation.

> The process may, for example, be due to a secretion by certain cells which phosphoresces as each drop is produced, and this process of secretion may

have a period of rest during the day and activity may be timed daily under ordinary conditions, and regulated by alternation of light and darkness. During the day there would be storage in the cell, and at night discharge. On the removal of the stimulus of light during the day this state of alternation of rest and action might persist for a long period.

Crozier (1920) performed a similar experiment on *Ptychodera* and *Glossobalanus*, two balanoglossid worms of Bermuda waters, and found that they would maintain for eight days a clear-cut diurnal rhythm of light production while remaining continually in the dark. The reciprocal experiment could not be made for even at night the expulsion of luminous materials was promptly inhibited by illumination.

Many other observations have been made on luminescence but not on its regular recurrence under constant experimental conditions.

MOVEMENTS OF EYE PIGMENTS AND RODS AND CONES

The various pigments of the arthropod eye, and the pigment and rods and cones of the vertebrate eye, may assume quite different positions at night from those found during the day. The movements normally occur daily at the time of sunrise and sunset and are occasioned by the changes in light intensity. They serve to regulate the amount of light reaching the photoreceptors. Such movements may persist in continuous illumination or darkness; therefore they are controlled, in part at least, by cyclical changes within the organism.

Kiesel (1894) was probably the first to observe persisting diurnal rhythms in the movements of pigment in the eyes of arthropods. He found that *Plusia gamma*, a noctuid moth, when kept in the dark continued to exhibit periodic changes in the eye for several weeks. At night the eye would "glow" and during the day would appear black when illuminated briefly. This was found to be due to the changing positions of the distal or iris pigment and Kiesel believed these movements were associated in some way with periods of sleeping and waking. Demoll (1911, 1917) confirmed Kiesel's observations and suggested that the evidence favored the view that the pigment cells were in some way under the control of the nervous system, for he thought the persisting periodicity was a nervous phenomenon. Demoll was well aware of the failures which had attended attempts to demonstrate motor connections to the pigment cells, but nevertheless believed that some kind of tonic impulses kept the pigment in the dark position, and that narcosis, sleep, or death, all of which brought about a movement to the light position, did so by removing this nervous influence.

The first observations on daily rhythms in the movements of pigment cells of crustacean eyes were made by Welsh (1930a). Under continuous illumination the distal pigment cells of *Macrobrachium*, a Cuban shrimp, were found to move distally at about 6 P.M. and remain in this position until sunrise the following morning. The proximal pigment did not exhibit this periodic movement. Anaesthesia and the cutting off of the circulation to the eye both prevented the characteristic distal movement of the pigment cells at the time of sunset. Thus it seemed that both the nervous system and some blood-borne material were involved in the persistence of the rhythm and it was concluded "that the direct control of the distal pigment cells is by way of the blood, and that the persistence of a diurnal rhythm under constant illumination parallels a periodicity in metabolism which is controlled by the nervous system". The earlier

work of Perkins (1928) and Koller (1928) had already shown the importance of hormones in controlling the chromatophores of crustaceans, and Bennitt (1932a) had demonstrated an interrelationship between the eyes of crustaceans, which strongly suggested a blood control of the retinal pigments. Bennitt (1932b) soon followed with a demonstration of a diurnal rhythm in the proximal pigment of *Cambarus* which were kept in constant darkness, and suggested that "Such a change is most likely to be brought about by a metabolic periodicity in the animal, acting through the circulation". Diurnal rhythms in the movements of one or more of the three sets of pigment cells of the eyes of several species of Bermudan shrimps and prawns were found to occur in continuous illumination or in constant darkness (Welsh, 1935); thus it appears that the phenomenon is fairly general among crustaceans.

The work of Kleinholz (1934, 1936) adds greatly to our understanding of retinal pigment control in crustaceans. He found that extracts of the eye stalks of various crustaceans, when injected into *Palaemonetes* while keeping them in the dark, brought about migration of the distal and reflecting pigments to their light positions. The active substance probably comes from the "blood-gland" (later the name was changed to "sinus-gland"), located by Hanstrom (1934); this will be discussed further in connection with diurnal rhythms in color change. The conclusive demonstration of the endocrine control of eye pigments in crustaceans, and the apparent importance of the nervous system in diurnal rhythms led the author (Welsh, 1936) to postulate either a rhythmic secretory cycle in the activity of the sinus gland, which continues under constant external conditions, or a cycle in nervous and general metabolic activity which affects the activity of the sinus-gland, hence the eye pigments. That there is apparently a detectable difference in the amount of active substance present in the eyestalks of *Palaemonetes* adapted to light and to darkness was shown by Kleinholz (1936) and later by Abramowitz (1937).

That persisting diurnal rhythms in the movements of retinal pigments of crustaceans are due to some well-established internal cyclical mechanism was shown by Welsh (1936) while working with *Anchistioides*, and more recently in work on *Homarus* and *Cambarus*, which has not been published. Crayfish have been kept in continuous darkness except for brief periods when observations were made, and at constant temperatures. At 7°C. the diurnal rhythms, evidenced by the covering and uncovering of the reflecting layer of the eye, have been observed to continue for about five months. At 21°C. they disappear after about four months.

Pigment movements in the eyes of living arthropods such as crustaceans are easy to observe (Welsh, 1930b); hence such forms are ideal for observations on retinal changes over a period of time. This, unfortunately, is not true of pigment and rod and cone movements in the eyes of vertebrates, for here only after the study of sections of the eyes of a number of animals is it possible to establish the positions of these retinal elements at any given time. This may account for earlier failure to observe diurnal rhythms in vertebrate retinas, or it may be that such are not marked or common in occurrence. In the eyes of the catfish, *Ameiurus nebulosus*, where the rods and cones are very large and their movements considerable, Welsh and Osborn (1937) have found that movements occur, characteristic of day and night when these fishes are kept in constant darkness. A few other fishes which were

used in a preliminary study show similar but less marked differences between "day-dark" and "night-dark" retinas.

Although it seems unnecessary to look further for obscure environmental factors which might be responsible for persisting daily rhythms Horstmann (1935), while repeating observations similar to those of Kiesel and Demoll on moths, apparently eliminated electrical changes in the atmosphere as a factor which might be responsible for diurnal changes in the eye.

COLOR CHANGE

Just as light production and retinal changes are physiological processes which are easily observed so is color change, when it occurs. Hence the activity of chromatophores has frequently been used in studies of nerve, hormone, and drug effects. Animals which change color by means of chromatophores may appear very different after they have been kept in complete darkness in comparison with their appearance when kept on a dark but illuminated background. Also the degree of dispersion of the pigment in the chromatophores, at night, may be quite different from that during the day. When certain animals are kept in constant darkness, and at a constant temperature, these day and night differences in coloration may persist for some time, thereby indicating the persistence of an internal cycle which is quite independent of environmental conditions. Gamble and Keeble (1900) were among the first to report a persisting periodic color change. *Hippolyte varians*, small crustaceans, were kept in the dark or in light for several days, undisturbed except for very brief periods when observations were made. The animals took on a nocturnal coloration in the early evening and maintained this until early morning when they assumed the color characteristic of the daytime. During the night the tissues were more transparent and the rate of heart beat was nearly twice as great as during the day. [Recent observations on *Hippolyte* (Kleinholz and Welsh, 1937) failed to confirm the independence of its pigmentary responses, and it seems probable that light conditions were not constant in the earlier work.] Further studies by Keeble and Gamble (1903–04) extended these observations to certain species of *Macromysis*, and the evidence for periodic changes in the general metabolic rate were strengthened by measurements of the acidity of the tissues. These were rather crude measurements made with litmus, but they revealed the interesting fact that liver and muscle became acid in the late afternoon and returned to an alkaline condition the following morning. The blood was always on the alkaline side, but their measurements were such as not to reveal pH changes which may have occurred. These workers believed that these physiological changes, which paralleled a change in color, might be responsible for the activity of the chromatophores but they failed to establish a definite relation. Their belief that a rhythm in color change was already established in the newly hatched Zoea larvae of *Palaemon squilla* seems hardly to be warranted from the data.

Schleip (1910) observed a periodic color change in *Dixippus morosus*, a phasmid, which was correlated with day and night and which persisted for a week in continuous darkness, but he offered little by way of explanation of the phenomenon. His observations were soon followed by similar observations on *Idothea*, an isopod, made by Menke (1911) who found the rhythm to persist for as long as 60 days when this animal was maintained in continuous darkness. Menke was also able to reverse the rhythm by lighting animals

at night and keeping them in the dark during the day. Following nine days of this they were then placed in the dark and the pigment cells were found to be contracted by day and expanded at night, the reverse of the normal condition. This reversed situation held for about a week. *Idothea* was found to have a periodicity in metabolism such as was seen in *Hippolyte* and Menke concluded that the persisting movements of the pigment in the chromatophores were due to internal changes which accompanied a periodicity in metabolism.

The idea that persisting diurnal rhythms in color change are associated in some way with a periodicity in metabolism, and therefore that the underlying control is essentially a chemical one, was replaced by a new hypothesis presented by Piéron (1914). After repeating Menke's observations on *Idothea*, Piéron, who thought that chromatophores were under direct nervous control, suggested that periodic discharges from certain nervous centers could account for persistent day and night differences in the color of the animal.

Persisting daily rhythms in color changes of vertebrates are apparently none too obvious for there are few records of such in the literature. Pauli (1926) observed this phenomenon in larvae of *Salamandra maculosa* for about one week when the larvae were kept in continuous darkness. When continuously illuminated these animals became dark and remained dark. An artificially induced reversed rhythm was always fainter and disappeared much earlier. *Phoxinus laevis* showed very slight changes in color, correlated with day and night, when kept in constant darkness. On the other hand *Xenopus laevis*, a South African toad, was found by Slome and Hogben (1929) to show marked day and night differences in coloration in the absence of light. They were attempting to identify the mechanism responsible for the contraction and expansion of the melanophores under normal conditions, and paid only slight attention to this periodic phenomenon. However, they say that because the nervous system seems to play an indirect rôle in the color changes of *Xenopus*, the mechanism responsible for the persisting rhythm may be a type of conditioned reflex.

A valuable contribution to our knowledge of color change and diurnal rhythms was made by Young (1935). He found that larvae and adults of *Lampetra planeri*, a lamprey, show very pronounced daily rhythms of color change, becoming pale at night and dark during the daytime. Continuous illumination produces maximal darkening and stops the diurnal rhythm. When larvae and adults of *Lampetra* are kept in total darkness, however, the diurnal rhythms usually persist, though diminished in extent. Young concluded that the melanophores of the lamprey are not under nervous control and showed that the removal of the pituitary resulted in maximal paling. Removal of the pineal complex in the larvae and the pineal complex and paired eyes of adult *L. planeri* resulted in the interruption of the diurnal rhythms and maximal darkening of the animal. This was not the first demonstration of the importance of the pituitary in color change, but it served to direct attention to the endocrine system as an important factor in the persisting daily rhythms of vertebrates.

Although Megušar (1912) and others knew that the removal of the eyes and eyestalks of crustaceans brought about a marked change in body coloration and an interruption of periodic color change, a correct interpretation of the results was not made because the obvious explanation was that nerve stimuli to the chromatophores were interrupted by the operation.

It was not known until the work of Koller (1928) and Perkins (1928) that the chromatophores of crustaceans were under direct hormone control. When this was discovered and when Perkins found the source of the pigment-concentrating hormone of *Palaemonetes* to be the eyestalks, the results obtained by earlier workers were subject to reinterpretation. If one examines the recent work on diurnal rhythms in the color changes of crustaceans, it is obvious that the part played by endocrines is an important one. Hanström (1934, 1935, 1937) and his students (Sjögren, 1934; Carlson, 1935, 1936) have shown that the chromatophore activating substance probably comes from a small gland present in the eyestalks of most crustaceans which Hanström has called the "sinusdrüse". The suggestion mentioned earlier that a cycle in the secretory activity of this gland might account for persisting diurnal rhythms in pigment migration in the eyes of crustaceans led Kleinholz (1937) and Abramowitz (1937) to investigate this possibility in connection with diurnal rhythms in color change. Kleinholz found that *Ligia baudiniana*, a Bermudan isopod, when kept in constant darkness, was pale at night and dark during the day. Injection of aqueous extracts of the heads caused paling of dark animals, so in order to test the idea that there might be differences in the amounts of hormone present during the day and during the night, extracts from the heads of dark and light *Ligia* were made and injected into dark animals. Both extracts were equally effective in concentrating the pigment of the melanophores; therefore Kleinholz concluded "that the diurnal pigmentary activity is not due to a cycle of exhaustion and elaboration of secretory material in the endocrine gland controlling the color changes".

Megušar (1912) had shown that *Uca* (*Gelasimus*) had a day-phase and night-phase in coloration when kept in constant darkness. This periodic change disappeared on removal of the eyestalks. Carlson (1936) confirmed this observation and showed that the paling which remained after the removal of the eyestalks was due to the removal of the sinus-gland. Injection of an extract of eyestalks caused a darkening of *Uca* (*Palaemonetes vulgaris* responds in a reverse manner). In order to test further the suggestion that a secretory cycle might be responsible for the diurnal rhythm in color changes of *Uca*, Abramowitz (1937), after standardization of methods of extracting and testing the active principle of the eyestalk, ran a series of experiments as follows. Eyestalks of *Uca* which had been kept in constant illumination and in constant darkness were removed and extracts were made both during the daytime and during the night. This yielded four sets of extracts which were then injected in equal amounts into test animals. Their effects were all essentially the same. This would seem to indicate that there is a constant amount of hormone present in the sinus-gland of *Uca*, regardless of the time of day, or the conditions of illumination. It is possible that the methods used by Kleinholz and Abramowitz on *Ligia* and *Uca* do not detect small differences which may exist in the content of the blood-gland, or it is possible that during the secretory phase the hormone is being elaborated as fast as it is secreted and an extraction would yield as much active material as would an extraction made during the non-secretory phase. There are also important differences between related animals, and while Abramowitz found no differences between the hormone content of *Uca* which had been kept in the dark and in the light, he did find larger amounts of the chromatophore hormone in the eyestalks of *Palaemonetes*

which had been kept in the light in comparison with those which had been kept in the dark, thereby confirming the results obtained earlier by Kleinholz on this same form. In this connection another important contribution should be mentioned, that of Rodewald (1934–35) who finds that the formation of the melanophore hormone in the pituitary of *Rana temporaria* goes on only under the influence of direct illumination. In the absence of light no melanophore hormone is formed, and after a sufficient period in the dark none can be obtained from the pituitary. In *Rana temporaria* there is no persisting rhythm in color change and none would be likely with such complete dependence of the pituitary on illumination for its activation.

GENERAL ACTIVITY AND METABOLIC RATE

The examples of persisting diurnal rhythms which have been discussed thus far are those involving a particular group of effectors such as luminescent organs, chromatophores, or pigment systems of the eye, and in one instance the movements of a group of receptors, the rods and cones. In several of these studies the particular phenomenon under observation has been said to vary with the metabolic rate or with general activity. Day and night variations in activity and in rate of metabolism have been quite widely studied or observed, and in a few instances satisfactory laboratory experiments have been performed under controlled conditions, so that it is no longer possible to dismiss these diurnal rhythms as due to some uncontrolled day and night differences in the environment.

Among the invertebrates the great majority of studies of diurnal rhythms in activity have been made on insects. Some of the earlier work which is interesting and suggestive, although its discussion here is not warranted, was reviewed by Bouvier (1922) and discussed along with further observations by Rau and Rau (1929). One of the first adequately controlled studies of 24-hour cycles in the movements of insects was made by Lutz (1932). By means of apparatus which recorded automatically any appreciable body or leg movement of the insects, Lutz proceeded to obtain activity records under normal day-night conditions and then in subsequent darkness, and also in darkness after periods of reversed illumination. He summarizes his results as follows,

> Two species of crickets and a subterranean grasshopper showed very definite diurnal rhythms which were continued in constant darkness, temperature and humidity. These rhythms were changed by reversed illumination and then the new rhythms were continued in constant darkness with the following exceptions. The crickets that were subjected to reversed illumination for only a short time showed a tendency to return to the old rhythm after a short time in constant darkness, and the *Stenopelmatus* individual that was inactive during a relatively long period of reversed illumination showed no effect of the reversing when it was subsequently active in constant darkness.

Park and his co-workers began a study of activity rhythms in nocturnal insects and certain other arthropods at about the same time that Lutz began his studies of this phenomenon. They find that there are three types of activities (Park and Sejba, 1935) which they speak of as environmentally controlled, inherent, and arhythmic. As attention has been directed, in this review, to rhythms which persist under constant external conditions, mention will be made of only the "inherent" rhythms which Park has described. Park and Keller (1932) observed under controlled conditions the activity of *Boletotherus cornutus*, a beetle. These animals were found to be much more active at night than during the day and this activity persisted under constant external con-

ditions. They also made the very interesting observation that beetles raised from the larval stage in continued darkness gave essentially the same performance as recently collected adults. Whether this indicates that the behavior of *Boletotherus* is "inherent" in the genetical sense or perhaps had been established in the larvae before they were removed to constant darkness seems to require further investigation. It is an important point which must be studied in forms other than mammals where conditioning *in utero* is possible. Another important aspect of the general problem which cannot be satisfactorily studied in mammals is the effect of prolonged fasting on diurnal rhythms. There are some who believe that diurnal rhythms in general activity are closely associated with feeding periods and result from the regular recurrence of hunger rhythms, but when clearly marked daily cycles persist during starvation periods up to 18 days in length, as shown by Park (1935) for *Spirobolus*, a millipede, this belief seems unjustified. The activity cycles of *Megalodacne heros* (Park and Sejba, 1935) are slightly altered when these beetles are kept under constant conditions, but periods of activity continue to occur during the night and there is little activity during the day.

Daily vertical movements of planktonic organisms have been widely studied under natural conditions (see review by Russell, 1927, and more recent papers by Clarke, 1933, 1934). Esterly (1917, 1919) demonstrated a "physiological rhythm" which he felt was in part responsible for the daily migrations of certain copepods. *Acartia* were kept in tall cylinders of sea water in continuous darkness. During the evening hours there was a marked increase in the numbers of animals in the upper levels, this being the time of day when this organism would normally be moving toward the surface. Because of the difficulty Esterly had in keeping these copepods living, observations could be made for only two days. As far as is known, this type of experiment has never been repeated and the possibility of an independent internal control of vertical movements of copepods and similar forms has not been generally accepted. Further evidence has been obtained from a study of the vertical migrations of deep-water animals in the sea which suggests that an internal physiological cycle may play some part in determining their movements (Welsh, Chace and Nunnemacher, 1937).

Stier (1933) observed a daily rhythm in the number of locomotor waves of the sea-cucumber, *Thyone briareus*. The number of waves of constriction passing along the body was found to increase between the hours of 4 P.M. and 2 A.M. This change in rate occurred when the animals were kept in a darkroom and illuminated only with a dim red light. This seems to be the only instance on record of a diurnal rhythm persisting under constant external conditions in any group of animals lower than the chordates excepting the arthropods.

The greatly increased activity of *Cambarus* which occurs in nature during the night persists for several months when these crayfishes are kept in constant darkness, as do the changes in the eye. There seems to be an endocrine control involved, just as there is in color changes of crustaceans, but this work is only now in progress and further evidence is necessary before this conclusion is warranted. Among the lower vertebrates there are few examples of persisting daily rhythms in general activity; they doubtless occur as do rhythms in color change, but attention has not been directed to them. An investigation of oxygen consumption in fresh-water fishes by Clausen (1936) re-

vealed rhythmic fluctuations, correlated with the time of day, which are indications of persisting activity rhythms. Clausen made hourly determinations of oxygen consumption of fishes kept at a constant temperature in containers which were covered to prevent stimulation. Besides differences in oxygen consumption between different species, he found variations of a regular nature over a 24-hour period. Large-mouth bass, *Huro salmoides*, consumed oxygen at a higher rate between 5 and 8 A.M. and again between 3 and 10 P.M. The black bull head, *Ameiurus melas*, exhibited irregularities in oxygen consumption between 5 and 10 P.M. Clausen states,

> The cause of these rhythmic fluctuations in oxygen consumption is not obvious. The constant environment of the experiments precludes any possibility of stimulation being the cause of these rhythmicalities. If this were the cause it would be impossible to place three fishes of three different species in the experimental chambers at the same time and obtain three different rhythms.

Spencer (1929) reported daily cycles in the activity of other fishes, but in the preliminary account the experimental conditions are not given.

Simpson and Galbraith (1905) and Wetmore (1921) measured the body temperature of birds and found this to be correlated with the times of normal activity and rest. Such nocturnal birds as owls have a higher temperature at night than during the day, while the majority of birds being normally more active during the day have a higher temperature at this time. These measurements were not made while the birds were under constant environmental conditions and the results are reported only because they occasionally appear in the literature on diurnal rhythms.

The experimental study of diurnal activity in mammals has been confined almost exclusively to rodents, and among the rodents the albino rat has received most attention. The nocturnal activity of the rat was recorded by Slonaker (1907), but the persistence of this greater activity at night, when rats are kept in constant darkness, was determined by Szymanski (1918) and Richter (1922). Richter attributed this, in part, to feeding habits. Most studies on periodic activity in rats (see review by Richter, 1927) have been concerned with the 2-hour rhythm which is a hunger response, and the 4 to 5 day cycle in females which has been found to be related to the estrous cycle. Little attention has been paid to daily rhythms. Recently experiments with the albino rat by Stier and Beck (communication) show that the activity rhythm persists for at least 58 days in constant darkness. Young rats born and kept in darkness show a definite diurnal activity rhythm which may have its peak during the daytime. If these young rats are exposed to normal daylight and darkness for one day, and then returned to continuous darkness, the major activity period thereafter occurs during the night.

A remarkably well-defined and persistent daily rhythm in the activity of *Peromyscus*, a forest deermouse, was discovered by Johnson (1926). *Peromyscus* were kept as long as seven months in continuous darkness and still showed a daily periodicity although the active phase was no longer at night. Reversed illumination, in another experiment, resulted in a reversal of activity, and the newly-acquired day-activity had persisted for 21 days when the experiment terminated. Attempts to establish artificial days of sixteen hours in length failed. To quote,

> In neither case was the normal twenty-four hour periodicity of the mice changed into or replaced by a sixteen-hour periodicity, although, as has been

shown, the actual time of activity may be quite readily shifted, the general plan of a twenty-four hour periodicity seems to be of a much more fundamental nature.

Young mice born in darkness, and kept for six weeks with their parents, were found to have an activity period that corresponded with that of the parents, which at that time was not in phase with the period of darkness outside. Johnson believed that the persisting activity rhythm of *Peromyscus* is not produced by, nor dependent upon, environmental conditions, but rather is an expression of an internal physiological rhythm.

The Japanese dancing mouse was found by Wolf (1930) to be more active at night, with one of two main periods of activity between 6 P.M. and midnight, and the second period in the early morning hours. These activity periods were maintained in constant darkness except for slight shifts in the onset of activity. Records were obtained on mice born and raised in darkness, and a marked periodicity in activity was found, although it was not correlated with outside day and night. Wolf recorded feeding and general activity separately and found the feeding periods so regularly distributed over periods of high and low activity that he concluded there was no apparent connection.

Davis (1933) found that increased nightly activity of a species of *Microtus*, the short-tailed vole of England, persisted for twenty-four days when the animals were kept in the dark.

Activity records of bats, when kept in constant darkness, with temperature and humidity relatively constant, were recently obtained by Griffin and Welsh (1937). A species of *Myotis* was found to be normally active for two to three hours beginning shortly after sunset. This activity persisted for four days in darkness, which was as long as this experiment was continued. Records were obtained on two *Pipistrellus* over a period of two weeks. One of these bats showed a daily period of activity in the early evening and a second period of lesser activity usually occurred in the early morning. In the other case there was an interesting correlation between times of disturbance and subsequent activity periods. Records were changed at approximately forty-eight hour intervals, the lights were then on in the darkroom for a brief period, and the bats were taken from the recording cages and fed. This failed to affect in any way the rhythm of one *Pipistrellus* but in the other there was a period of activity soon after feeding, a second period approximately twenty-four hours later, and if recording continued uninterrupted for the full two days, a third period near the end of the second day would appear. These periods were related in no regular manner to solar time but were determined by the period of illumination and feeding. The fact that a second and third activity period might appear, after intervals of twenty-four and forty-eight hours, with no further outside disturbance, indicates the presence of internal cyclical processes operating in periods of twenty-four hours.

Browman (1936) has used the albino rat in studies of activity cycles and finds the peak of daily activity, during normal day-night, or during controlled twelve-hour periods of artificial light and darkness, occurs during the night or during darkness. Reversal of the light and dark periods causes a subsequent reversal of daily activity. Constant artificial light for a period of weeks causes fluctuations in the daily activity rhythms of female rats. Peaks of activity may occur for five to six days during the solar night, then, after one to three days of irregular activity, the peaks occur during the solar day, and so on. Rats in constant dark-

ness, and blinded rats, maintain the rhythm of daily activity with which they enter the dark.

A convincing demonstration of an internal 24-hour cycle of metabolism in rats and man has been made by Werthessen (1936, 1937). Using an apparatus which gave a continuous measurement of oxygen consumption and intermittent determinations of carbon dioxide production, Werthessen proceeded to determine these values during thirty-six hour fasts. Both normal rats and rats which had been trained to eat at twenty-four hour intervals were used. The results were essentially the same. The rate of oxygen consumption and carbon dioxide production was high at the beginning of the run, dropped to a minimum at about the sixteenth hour and then rose to a second maximum near the twenty-fourth hour. Following this, unpredictable variation set in. Experiments on four men, using standard apparatus, yielded essentially similar results. These results are quite surprising in view of the general assumption that the basal metabolic rate remains relatively constant, over a period of time, if conditions are kept constant. They confirm the earlier findings of Horst, Mendel, and Benedict (1934) on the rat.

Finally, one of the most recent studies of rhythmic phenomena in the rat (Hemmingsen and Krarup, 1937) has established the very interesting fact that certain phases in the estrous cycle occur at certain definite times in the diurnal cycle. Under normal day-night conditions the maximum of estrus takes place at about midnight, at intervals of four days. Under reversed lighting conditions the maximum of estrus is shifted to midday. These investigators also found it impossible to establish artificial days of sixteen hours, made up of eight hours of light and eight of dark. They say, "Even after two months a struggle was still going on between the tendency to display the activity in the dark periods and the tendency to have one pronounced period of activity every twenty-four hours." The obvious conclusion from this work is that the same internal mechanism which is responsible for maintaining, in the rat, an estrous cycle of a definite duration with its maximum occuring in the dark may be, in part, responsible for the maintenance of 24-hour cycles of muscular activity.

OTHER MANIFESTATIONS OF DIURNAL RHYTHMS

A very considerable group of observations of diurnal rhythms in animals will be omitted from this review, partly for lack of space, and partly because they do not satisfy the requirements stated earlier that in most instances only those rhythms which have been shown to persist, with external conditions controlled, would be discussed. It is inevitable that some studies which satisfy this requirement may be overlooked.

There are a certain number of additional important and interesting studies which emphasize the widespread occurrence of 24-hour cycles and some of these have been chosen to emphasize the desirability of taking these daily variations into consideration in the conduct of certain experiments which continue over a period of twenty-four hours or longer.

If we examine the field of parasitology we find several instances of modified behavior of the parasite, brought about by the daily cycles in activity of the host. One classical example is the daily migration of the microfilariae of *Wuchereria bancrofti* which infect man, (reported by Manson 1879–81, and studied since by numerous workers) in regions where a night-flying mosquito is the transmitter. These microfilariae appear in the peripheral cir-

culation at night and disappear during the day. Chandler (1930) says, "The stimulus which times the appearance of the embryos in the blood is in some way connected with cessation of activity on the part of the host, for it is gradually reversed in people who sleep by day and work by night; yet sleep itself is not the factor, since the embryos begin to appear before the usual sleeping hours." While the factor or factors which govern the periodicity of the microfilariae are not known, it is fairly clear that it is neither an inherent nor an acquired rhythm in the parasite, but some change which takes place in the blood of the host which stimulates them to migate. Boyd (1929) describes a 24-hour cycle in the reproduction of the malarial parasite of birds, *Plasmodium cathemerium*. Changes in length of day and night, reversed illumination, and constant illumination all modify the reproductive activity of this parasite. Boyd concluded the effects were due to changes in the periods of activity of the host. Boughton, Atchley and Eskridge (1935) in a similar way modified the diurnal oocyst production of the sparrow coccidium, *Isospora*, and likewise concluded that it was controlled by host activity.

The diurnal spermatogenic cycle in the house sparrow, *Passer domesticus*, studied by Riley (1937), and the daily deposits of dentin and enamel in the incisor of the rat, observed by Schour and Steadman (1935) are further examples of physiological phenomena which, in order to be understood, must be considered in relation to the general diurnal rhythm in the activities of the organism as a whole. They appear to be entirely dependent on regular changes in the metabolic activity of the animal in which they are found which may in turn depend on environmental changes. On the other hand, ovulation in the common fowl (Warren and Scott, 1936) is, to some extent, cyclical under relatively constant environmental conditions. With conditions normal most eggs are laid by hens between 7 A.M. and 5 P.M. After one to two weeks of continuous illumination Warren and Scott found that egg-laying was fairly evenly distributed over twenty-four hour periods. Under conditions of reversed illumination most of the eggs were produced during the night. These experiments were performed with the birds in individual compartments. Quite different results were obtained when they were subjected to various conditions of illumination in laying houses to which they were accustomed. Here under continuous red light of a low intensity, which was the nearest approach to continuous darkness, over 75 per cent of the eggs continued to be produced in the day period. In the same laying pens under continuous artificial light a group of birds continued to produce most of their eggs during the day for a period of eighteen days. Artificial light only at night then caused complete reversal by the fifth day, but when this was followed by a second period of continuous illumination the birds returned to day laying with a few eggs produced in the early morning and evening. They say that the birds may have been able to escape from the direct rays of the light during the night, but this would not explain the return to the usual day period of laying after a period of complete reversal. The different results obtained when birds were kept in individual compartments and in the usual laying houses they believe may be ascribed to a "psychological" effect of unaccustomed surroundings. After discussing the rôle played by hormones in the sexual cycle of birds they conclude "Since the effect (of light) on laying is regulatory rather than stimulatory, it seems improbable that the hormone theory would

apply here." This conclusion seems to be unwarranted as there are various processes which are "regulated" by hormones and this control may either be dependent on or partially independent of external regulatory stimuli.

"Time sense" in bees, which has been studied by Behling (1929), Wahl (1933), Kalmus (1935) and others is evidence of an internal rhythm which operates in 24-hour cycles, for bees may be trained to seek food only at intervals of this length. Ants and termites, however, may be trained to seek their food at other intervals (Grabensberger, 1933), although they apparently exhibit daily activity cycles under constant external conditions. The differences between the bees and the ants and termites appears to be in their normal feeding habits; the bees seeking food at times when nectar and pollen are available. Such times are restricted to a definite period of the day. The diurnal periodicity of emergence of *Drosophila* from the puparia (Bremer, 1926; Bünning, 1935) persists after keeping this species through several generations under alternating periods of light and dark of eight hours or eighteen hours duration.

Limited space allows no more than the citation of certain recent reviews which deal with the very considerable literature on diurnal rhythms in man. Studies of diurnal variations in human performance, which have been made primarily by psychologists, have been adequately reviewed by Freeman and Hovland (1934). The review by Kleitman (1929) covers the large literature on sleep which had appeared during the previous decade or more. The recent review by Jores (1937) includes many studies on 24-hour cycles in man such as the glycogen cycle of the liver (see also Forsgren, 1935). So many factors have been found to affect the "diurnal curves" of man that the conclusions are most confusing. Man is a poor experimental animal and, at present, it would seem that a more complete understanding of the internal processes responsible for diurnal rhythms may come first from study of the lower animals.

DISCUSSION

From the studies of diurnal rhythms there are a few important points which deserve special emphasis. It is apparent that they are of relatively common occurrence and are manifest in diverse ways. It is also apparent that they may persist for long periods of time in the absence of changes in the external environment which are responsible for their origin, the most important being light. The periods of the rhythm, or perhaps better the phases of the cycle, may be experimentally reversed by reversed illumination; the lengths of the periods may be temporarily altered by artificial days longer or shorter than twenty-four hours; the regularity of the rhythm may be disturbed by constant illumination, but as long as the animal is left intact there is a tendency to return to a 24-hour cycle when subsequently placed in constant darkness. The presence of some internal physiological process or processes operating in periods of twenty-four hours' duration must be admitted. A complete understanding of all phases of a cycle, in any one organism, is far from being realized at the present time. The mechanism which causes an animal to change color at the time of sunset may be quite different from that which awakens a nocturnal animal such as a bat. The problem is to determine whether, for a given animal, there is a timing mechanism which operates independently or whether there is a series of events which operate in a definite sequence, any one of which is dependent on the preceding step.

Endocrine glands and their hormones play an important rôle in color change and movements of eye pigments. The activity of these glands is influenced by the presence or absence of light, but thus far there is no convincing evidence that there is a persisting cycle in secretory activity under constant external conditions.

The effect of anaesthesia and other indirect evidence such as the ease with which activity periods may be shifted about suggest that the nervous system may play an important rôle in diurnal periodicity. This is more than likely in pigmentary changes where the blood gland and that part of the pituitary which secretes the chromatophore-activating hormone are under nervous control.

Regular daily fluctuations in the rate of metabolism of a fasting animal, kept under constant external conditions, must be determined partly by regular changes in the nervous and endocrine systems; it is possible that these variations in metabolism, in turn, affect the coordinating systems. Instead of some one physiological process being responsible for the persistence of diurnal rhythms there would then be a series of processes operating in a cycle. The evidence at hand at the present time suggests that this may be true although in no single organism has a nervous-endocrine-metabolic sequence of twenty-four hours' duration been demonstrated. Until there is more complete experimental data diurnal rhythms or 24-hour cycles will continue to be explained in the same indefinite terms which were applied to the sexual cycle not many years past.

LIST OF LITERATURE

Abramowitz, A. A. 1937. The chromatophorotropic hormone of the crustacea: standardization, properties, and physiology of the eye-stalk glands. *Biol. Bull.*, 72: 344–365.

Beling, I. 1929. Über das Zeitgedächtnis der Bienen. *Zeit. f. vergl. Physiol.*, 9: 259–338.

Bennitt, R. 1932a. Physiological interrelationship in the eyes of decapod Crustacea. *Physiol. Zool.*, 5: 49–64.

——. 1932b. Diurnal rhythm in the proximal pigment cells of the crayfish retina. *Physiol. Zool.*, 5: 65–69.

Boughton, D. C., F. O. Atchley, and L. C. Eskridge. 1935. Experimental modification of the diurnal oocyst-production of the sparrow coccidium. *Jour. Exp. Zool.*, 70: 55–74.

Bouvier, E. L. 1922. The Psychic Life of Insects. Translation by L. O. Howard. The Century Co., *New York.*

Boyd, G. H. 1929. Experimental modification of the reproductive activity of *Plasmodium cathemerium. Jour. Exp. Zool.* 54: 111–126.

Bremer, H. 1926. Über die tageszeitliche Konstanz im Schlüpftermine der Imagines einiger Inseckten und ihre experimentelle Beeinflussbarkeit. *Zeit. f. wiss. Insektenbiol.*, 21: 209–216.

Browman, L. G. 1936. Light in its relation to activity and estrous rhythms in the albino rat. *Anat. Rec.*, 67, Supp. 1, p. 107.

Buck, J. B. 1937. Studies on the firefly. I. The effect of light and other agents on flashing in *Photinus pyralis*, with special reference to periodicity and diurnal rhythm. *Physiol. Zool.*, 10: 45–58.

Bünning, E. 1935. Zur Kenntnis der endonomen Tagesrhythmik bei Insekten und bei Pflanzen. *Berichte der deutschen botanischen Gesellschaft*, 53: 594–623.

Carlson, S. Ph. 1935. The color change in *Uca pugilator. Proc. Nat. Acad. Sci., Wash.*, 21: 549–551.

——. 1936. Color changes in brachyura crustaceans, especially in *Uca pugilator. Kungl. Fysiografiska Sällskapets. I Lund Förhandlingar*, 6: 1–18.

Carpenter, J. R. 1932. Diurnal fluctuations in communities adjoining the forest edge near Urbana, Illinois. *Proc. Oklahoma Acad. Sci.*, 14: 29–31.

Chandler, A. C. 1930. Introduction to Human Parasitology. 4th ed. John Wiley & Sons, *New York.*

Clarke, G. L. 1933. Diurnal migration of plankton in the Gulf of Maine and its correlation with changes in submarine irradiation. *Biol. Bull.*, 65: 402–436.

——. 1934. Further observations on the diurnal migration of copepods in the Gulf of Maine. *Biol. Bull.*, 67: 432–455.

CLAUSEN, R. G. 1936. Oxygen consumption in fresh water fishes. *Ecology*, 17: 216–226.

CROZIER, W. J. 1920. Some points concerning adaptation. 4. Persisting rhythm of light production in balanoglossids. *Anat. Rec.*, 20: 186.

DAVIS, D. H. S. 1933. Rhythmic activity in the short-tailed vole, *Microtus*. *Jour. Anim. Ecology*, 2: 232–239.

DEMOLL, R. 1911. Über die Wanderung des Irispigments in Facettenauge. *Zool. Jahrb., Physiol.*, 30: 159–180.

——. 1917. Sinnesorgane der Arthropoden. F. Vieweg & Sohn, *Braunschweig*.

ESTERLY, C. O. 1917. The occurrence of a rhythm in the geotropism of two species of plankton copepods when certain recurring external conditions are absent. *Univ. California Pub. Zool.*, 16: 393–400.

——. 1919. Reactions of various plankton animals with reference to their diurnal migrations. *Univ. California Pub. Zool.*, 19: 1–83.

FORSGREN, E. 1935. Über die Rhythmik der Leberfunktion des Stoffwechsels und des Schlafes. *Stockholm*.

FREEMAN, G. L., and C. I. HOVLAND. 1934. Diurnal variations in performance and related physiological processes. *Psych. Bull.* 31: 777–799.

GAMBLE, F. W., and F. W. KEEBLE. 1900. *Hippolyte varians:* a study in colour-change. *Quart. Jour. Micro. Sci.*, 43: 589–698.

GRABENSBERGER, W. 1933. Untersuchungen über das Zeitgedächtnis der Ameisen und Termiten. *Zeit. f. vergl. Physiol.*, 20: 1–54.

GRIFFIN, D. R. and J. H. WELSH. 1937. Activity rhythms in bats under constant external conditions. *Jour. Mammal.*, 18: 337–342.

HANSTRÖM, B. 1934. Über das Organ X, eine inkretorische Gehirndrüse der Crustacean. *Psychiat. en Neurol. Bladen*, 38: 405–425.

———. 1935. Preliminary report on the probable connection between the blood gland and the chromatophore activator in decapod crustaceans. *Proc. Nat. Acad. Sci., Washington*, 21: 584–585.

——. 1937. Inkretorische Organe und Hormonefunktionen bei den Wirbellosen. *Ergebnisse der Biologie*, 14: 143–224.

HEMMINGSEN, A. M. and N. B. KRARUP. 1937. Rhythmic diurnal variations in the oestrous phenomena of the rat and their susceptibility to light and dark. *Det. Kgl. Danske Videnskabernes Selskab., Biologiske Meddelelser*, 13: 1–61.

HORST, K., L. B. MENDEL, and F. G. BENEDICT. 1934. The effect of some external factors upon the metabolism of the rat. *Jour. Nutrition*, 7: 277–303.

HORSTMANN, E. 1935. Die tagesperiodischen Pigmentwanderungen in Facettenauge von Nachtschmetterlingen. *Biol. Centralbl.* 55: 93–97.

JOHNSON, M. S. 1926. Activity and distribution of certain wild mice in relation to biotic communities. *Jour. Mammal.* 7: 245–277.

JORES, A. 1937. Die 24-Stunden-Periodik in der Biologie. *Tabulae Biologicae*, 14: 77–109.

KALMUS, H. 1935. Periodizitat und Autochronie (Ideochronie) als zeitregelnde Eigenschaften der Organismen. *Biologia Generalis*, 11: 93–114.

KEEBLE, F. W., and F. W. GAMBLE. 1903–04. The colour-physiology of higher crustaceans. *Phil. Trans. Roy. Soc. London*, B, 196: 295–388.

KIESEL, A. 1894. Untersuchungen zur Physiologie des facettirten Auges. *Sitzungsber. kais. Akad. Wiss., Wien*, 103: 97–139.

KLEINHOLZ, L. H. 1934. Eye-stalk hormone and the movement of distal retinal pigment in *Palaemonetes*. *Proc. Nat. Acad. Sci., Wash.*, 20: 659–661.

——. 1936. Crustacean eye-stalk hormone and retinal pigment migration. *Biol. Bull.*, 70: 159–184.

——. 1937. Studies in the pigmentary system of Crustacea. 1. Color changes and diurnal rhythm in *Ligia baudiniana*. *Biol. Bull.*, 72: 24–36.

——, and J. H. WELSH. 1937. Colour changes in *Hippolyte varians*. *Nature*, 140: 851.

KLEITMAN, N. 1929. Sleep. *Physiol. Rev.*, 9: 624–665.

KOLLER, G. 1928. Versuch über die inkretorischen Vorgänge beim Garneelenfarbwechsel. *Zeit. f. vergl. Physiol.*, 8: 601–612.

LUTZ, F. E. 1932. Experiments with orthoptera concerning diurnal rhythm. *Am. Mus. Novitates*, No. 550.

MANSON, P. 1879–81. On the periodicity of filarial migrations to and from the circulation. *Quekett Micro. Club. Jour.*, 6: 239–248.

MEGUŠAR, F. 1912. Experimente über den Farbwechsel der Crustacean. *Arch. f. entwick.-mech.*, 33: 462–665.

MENKE, H. 1911. Periodische Bewegungen und ihr Zusammenhang mit Licht und Stoffenwechsel. *Arch. ges. Physiol.*, 146: 37–91.

MOORE, B. 1909. Observations of certain marine organisms of (a) variations in reactions to light, and (b) diurnal periodicity of phosphorescence. *Biochem. Jour.*, 4: 1–29.

PARK, O. 1935. Studies in nocturnal ecology. III. Recording apparatus and further analysis of activity rhythm. *Ecology*, 16: 152–163.

PARK, O., and J. G. KELLER. 1932. Preliminary analysis of activity rhythm in nocturnal forest insects. *Ecology*, 13: 335–346.

PARK, O., and O. ŠEJBA. 1935. Studies in nocturnal ecology. IV. *Megalodacne heros*. *Ecology*, 16: 164–172.

PAULI, W. 1926. Versuch über den physiologischen Farbenwechsel der Salamanderlarve und der Pfrille. *Zeit. f. wiss. Zool.*, 128: 421–508.

PERKINS, E. B. 1928. Color changes in crustaceans, especially in *Palaemonetes*. *Jour. Exp. Zool.*, 50: 71–105.

PIÉRON, H. 1914. Recherches sur le comportement chromatique des invertébés et en particulier des Isopodes. *Bull. sci. de la France et Belg.*, 48: 30–79.

RAU, P., and N. RAU. 1929. The sex attraction and rhythmic periodicity in giant saturniid moths. *Trans. Acad. Sci. St. Louis*, 26: 81–221.

RICHTER, C. P. 1922. Behavioristic study of the activity of the rat. *Comp. Psych. Monographs*, 1.

——. 1927. Animal behavior and internal drives. QUART. REV. BIOL., 2, 307–343.

RILEY, G. M. 1937. Experimental studies on spermatogenesis in the house sparrow, *Passer domesticus* (Linnaeus). *Anat. Rec.*, 67: 327–346.

RODEWALD, W. 1934–35. Die Wirkung des Lichtes auf die Hypophyse von *Rana temporaria* L. *Zeit. f. vergl. Physiol.*, 21: 767–800.

RUSSELL, F. S. 1927. The vertical distribution of plankton in the sea. *Biol. Reviews*, 2: 213–262.

SCHLEIP, W. 1910. Der Farbenwechsel von *Dixippus morosus*. *Zool. Jahrb.*, 30: 45–132.

SCHOUR, I. and S. R. STEADMAN. 1935. The growth pattern and daily rhythm of the incisor of the rat. *Anat. Rev.*, 63: 325–333.

SIMPSON, S., and J. J. GALBRAITH. 1905. An investigation into the diurnal variation of the body temperature of nocturnal and other birds, and a few mammals. *Jour. Physiol.*, 33: 225–238.

SJÖGREN, S. 1934. Die Blutdrüse und ihre Ausbildung bei den Decapoden. *Zool. Jahrb.*, 58: 145–170.

SLOME, D., and L. T. HOGBEN. 1929. The time factor in the chromatic responses of *Xenopus laevis*. *Trans. Roy. Soc. South Africa*, 17: 141–150.

SLONAKER, J. R. 1907. The normal activity of the white rat at different ages. *Jour. Comp. Neur. and Psychol.*, 17: 342–359.

SPENCER, W. P. 1929. Day and night periodicity in four species of freshwater fish. *Anat. Rec.*, 44: 197.

STIER, T. J. B. 1933. Diurnal changes in activities and geotropism in *Thyone briareus*. *Biol. Bull.*, 64: 326–332.

STIER, T. J. B., and S. BECK. (Communication).

STOPPEL, R. 1916. Die Abhängigkeit der Schlafwegungen von *Phaseolus multiflorus* von verschiedenen Aussenfaktoren. *Zeit. f. Botanik.*, 8: 609–684.

SZYMANSKI, J. S. 1918. Die Verteilung der Ruhe- und Aktivitätsperioden bei weissen Ratten und Tanzmäusen. *Arch. ges. Physiol.*, 171: 324–347.

VÖLKER, H. 1926. Über die tagesperiodischen Schwankungen einiger Lebensvorgänge des Menschen. *Arch. ges. Physiol.*, 215: 43–77.

WAHL, O. 1933. Neue Untersuchungen über des Zeitgedächtnis der Bienen. *Zeit. f. vergl. Physiol.*, 16: 529–589.

WARREN, D. C., and H. M. SCOTT. 1936. Influence of light on ovulation in the fowl. *Jour. Exp. Zool.*, 74: 137–156.

WELSH, J. H. 1930a. Diurnal rhythm of the distal pigment cells in the eyes of certain crustaceans. *Proc. Nat. Acad. Sci., Wash.*, 16: 386–395.

——. 1930b. The mechanics of migration of the distal pigment cells in the eyes of *Palaemonetes*. *Jour. Exp. Zool.*, 56: 459–494.

——. 1935. Further evidence of a diurnal rhythm in the movement of pigment cells in the eyes of crustaceans. *Biol. Bull.*, 68: 247–252.

——. 1936. Diurnal movements of the eye pigments of *Anchistioides*. *Biol. Bull.*, 70: 217–227.

——. F. A. CHACE, JR. and R. F. NUNNEMACHER. 1937. The diurnal migration of deep-water animals. *Biol. Bull.*, 73: 185–196.

WELSH, J. H., and C. M. OSBORN. 1937. Diurnal changes in the retina of the catfish, *Ameiurus nebulosus*. *Jour. Comp. Neur.*, 66: 349–359.

WERTHESSEN, N. T. 1936. A study of the variation in the metabolic rate of man and rats. *Anat. Rec.*, 67, Supp. 1, p. 43.

——. 1937. The significance of subnormal respiratory quotient values induced by controlled feeding in the rat. *Am. J. Physiol.*, 120: 458–465.

WETMORE, A. 1921. A study of the body temperature of birds. *Smithson. Misc. Coll.*, 72: 1–52.

WOLF, E. 1930. Die Aktivität der japanischen Tanzmaus and ihre rhythmische Verteilung. *Zeit. f. vergl. Physiol.*, 11: 321–344.

YOUNG, J. Z. 1935. The photoreceptors of lampreys. II. The functions of the pineal complex. *Jour. Exp. Biol.*, 12: 254–270.

WHAT ARE THE GENES?

II. THE PHYSICO-CHEMICAL PICTURE; CONCLUSIONS

By ADDISON GULICK

Department of Biochemistry, University of Missouri, Columbia, Missouri

COMPOSITION OF SPERMATOZOA AND NUCLEI

THE spermatozoan nucleus or head is the most concentrated packet of genes known to science, and as such is a subject of especial interest. Following the description by Marcus (1921) the human spermatozoan head has a flattened eliptical shape, about .0038 mm. or 3.8 μ long by 3.2 μ in width, so that lying flat it will cover an area of field that is almost exactly 9 square μ in extent. Its thickness, which Marcus fails to discuss, is not over 2 μ at its maximum point, and it tapers down very greatly in other portions, so that an average thickness of 1.5 μ is a fairly liberal estimate. Multiplying the projected area, 9 square μ by the average thickness, it is evident that the approximate volume of the head may be estimated as 13.5 cu. μ. This volume corresponds to that taken up by 13.5 $\gamma\gamma$ (.0000000135 mg. or 13.5×10^{-9} mg.) of water. The actual weight of one sperm head will be several $\gamma\gamma$ in excess of 13.5, as it is unusually dense for a living structure and behaves as a somewhat heavy body when centrifuged. The dry content of organic matter will lie approximately at 5 to 6 $\gamma\gamma$. Practically the whole of the human sperm head, according to Marcus, is nucleus, there being no terminal perforatorium, such as some spermatozoa exhibit, and only an excessively thin cup-shaped film of non-nuclear material covering the basal portion. A rib-like exoskeleton, detectable by ultraviolet light, claims only a negligible fraction of the whole volume. A small vacuole seems to be the only detectable interruption in the homogeneous interior of the head.

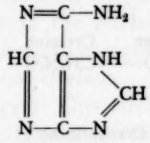
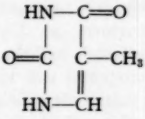
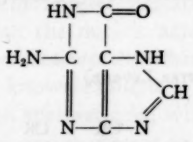
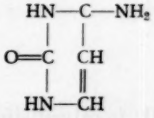
Among other animal species sperm heads are to be found both larger and smaller than in man. That of the fruit-fly, *Drosophila*, so important in genetic studies, has a volume between 0.5 and 0.6 cu. μ (Morgan, 1922). Almost without exception sperm heads differ from usual forms of nuclei in that under the microscope they present the picture of being composed of "chromatin" in a compacted form, largely without the presence of nuclear sap or appreciable masses of any other material than chromatin.

In many forms of animals the entire testicle matures simultaneously, and various biochemists, beginning with Miescher (1874a, 1897), have found it possible to collect and separate sperm heads in sufficient quantity to carry out extensive chemical studies on these practically pure samples of chromatin, the same material, to all external appearances, that is seen in the form of chromosomes when a nucleus undergoes division, and which has repeatedly been identified by geneticists, perhaps a little rashly, as the physical basis of the Mendelian mechanics of heredity. The classic material for these investigations has come from the Rhine

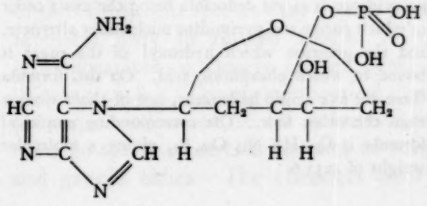
salmon during its spawning migration up the river.

In each species that has been examined, the sperm head chromatin has a surprisingly constant and homogeneous composition. Roughly 96 per cent of the alcohol-ether insoluble solids in sperm heads collected from Rhine salmon consists of a distinctive organic salt known as salmin nucleate, a salt-like combination of thymonucleic acid with a protamine, a very basic protein complex. The structural chemistry of these two ingredients, the acid and the protein, has now been very largely elucidated. (Miescher and Schmiedeberg, 1896; Schmiedeberg, 1900, Burian, 1904, 1906.)

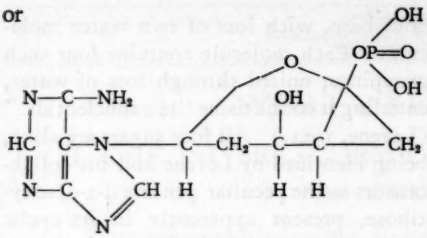
TABLE 1

PURINES		PYRIMIDINES	
Adenine or 6-amino purine		Thymine or 2-6-oxy-5-methyl pyrimidine	
Guanine or 2-amino-6-oxy purine		Cytosine or 2-oxy-6-amino pyrimidine	

The acid part of the complex seems to be more uniform for various species than the basic portion; being, so far as known, identical in salmon sperm with that from spermatozoa of other fishes, and from mammalian testicle, thymus, spleen, thyroid, liver, kidney, brain, mammary glands, placenta, intestine, etc., and closely related to materials from pancreas and from some bacteria, all of these being structures rich in nuclear substance. (Levene and Bass, 1931.) It is an equimolecular combination of a distinctive sugar with phosphoric acid and a nitrogenous base, with loss of two water molecules. Each molecule contains four such groupings, united through loss of water, entitling it to the name "tetranucleotide." (Levene, 1921.) All four sugars are alike, being identified by Levene and his collaborators as the peculiar pentose d-2-desoxyribose, present apparently in its cyclic form. (Levene, Mikeska and Mori, 1930.) The bases on the other hand are all different, consisting of two purines and two pyrimidines (Table 1). The bonding of each base to its sugar is after the manner of a glucoside, the purines being attached apparently on position (7) (right-hand-NH-), and the pyrimidines on position (3) (lower left -NH-). The phosphoric acid radicle is attached to one of the remaining hydroxyls of the sugar. Thus the adenine mononucleotide should be allowed one of the following structural formulae, the other three component mononucleotides being built in analogous manner.



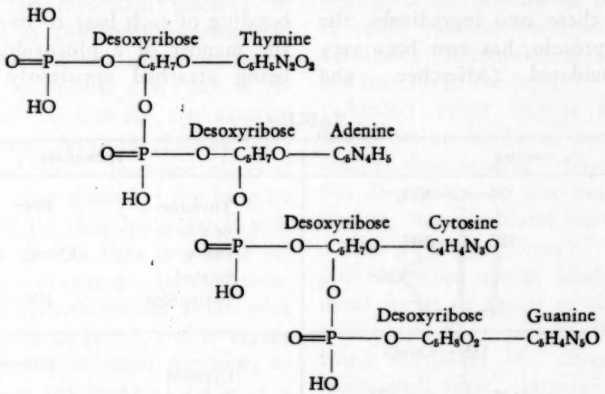
or



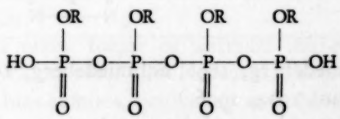
The mode of union of the four mononucleotids to constitute a tetranucleotid is still involved in some controversy. Levene (1921) gives reasons for inferring that it is by an ester linkage between phosphoric acid, and that the purine and pyrimidine mononucleotides alternate with each other.

His titration curves indicate that one of the five acidic hydrogens still remaining is much weaker than the other four. Hence the complete molecule is provisionally represented with the following configuration, the only structural points on which no evidence is as yet deducible being the exact order in which purine and pyrimidine nucleotides alternate, and the question which hydroxyl of the sugar is bound to which phosphoric acid. On this formula there are five acidic hydrogens, one of them weaker than the other four. The corresponding empirical formula is $C_{39}\ H_{51}\ N_{15}\ O_{25}\ P_4$, giving a molecular weight of 1253.6.

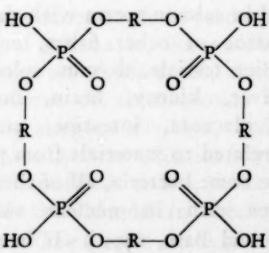
We give below, abbreviated, a formula which was revived by Thannhauser (1934), after it had first been suggested and rejected by Levene. (Klein and Rossi, 1935.) The arguments in its favor are drawn from digestion experiments by Thannhauser. Also a cyclic formula, as indicated below, has been suggested by Takahashi (1932) to accord with his belief that the substance is indigestible to monophosphoric-esterases until started by a diphosphoric-esterase. As neither of these formulae conform to the conditions of ionization indicated by Levene's titration curves, we shall base our further considerations on Levene's tentative formula given herewith.



THYMONUCLEIC ACID (AFTER LEVENE)



Thannhauser



Takahashi

The current impression of a systematic distinction between plant and animal nucleic acids is only valid if we limit attention to the two commonest members of the class. (Levene and Bass, 1931.) A nucleic acid which has been found in wheat germ and yeast differs from the above-described thymo-nucleic acid in having ribose instead of desoxyribose, and uracil in place of its methyl derivative, thymine. But ribose is also found in a specialized polynucleotide of the mammalian pancreas, in the adenine mononucleotide of muscle tissue and in the guanine mononucleotide of various mammalian gland tissues. On the other hand the nucleic acid of tubercle bacilli is credited with desoxyribose and with both thymine and uracil, as well as 5-methylcytosine. The bases in the nucleic acid from the pea are reported to coincide with those from mammalian thymus. (Kiesel and Belozerski, 1934.) Obviously any attempt to state the taxonomic distribution of the nucleic acids is quite premature.

The base to which the nucleic acid is attached also shows noteworthy characteristics. The best known example is the protamine of salmon spermatozoa, which is designated salmin, and is present as the organic salt, salmin nucleate. (Miescher, 1874b; Piccard, 1874; Kossel and Kutscher, 1900; Kossel, 1903; Abderhalden, 1904; Kossel, 1928.)

Hydrolysis shows that the base is a protein composed entirely of four familiar and frequently described amino acids, occurring either in the proportions, 10 arginine + 2 proline + 2 serine + 1 valine − $14H_2O$, or else perhaps 12 arginine + 3 proline + 2 serine + 1 valine − $17H_2O$. These two formulae yield extremely similar figures for the acid-base balance, the former representing a reaction weight (as base) of 188.9, and the latter giving the figure 187.9. On the basis of the first alternative the elementary composition will be $C_{81}H_{158}N_{45}O_{18}$ or a small multiple of this, corresponding to a minimum molecular weight of 2046.6. Its basic character is derived from the free NH_2 groups in the guanidine part of the arginine, and also probably from a residual unattached alpha-amino nitrogen. Each molecule, if we assume the minimum permissible formula, should have 10 strongly basic groupings, and presumably also one that is weaker.

One hundred parts of native salmine nucleate contains, according to Miescher's analyses, 37.35 parts of salmine, the remainder being the nucleic acid (Miescher and Schmiedeberg, 1896). But if allowance is made for a supposed trifling contamination, the per cent will be a shade lower, as pointed out by Burian (1906). These figures fit almost perfectly the ratio of four protamine molecules of the above minimum size, to eleven thymonucleic acid molecules, to make the naturally occurring salt. In other words the average formula should be

$$(C_{81}H_{158}N_{45}O_{18})_4(C_{89}H_{81}N_{15}O_{28}P_4)_{11}, \text{ or}$$

$$C_{769}H_{1181}N_{345}O_{347}P_{44}$$

If the supposed basic and acidic valencies of its components are correct, all of the eleven basic nitrogens will be functioning in each unit portion of the protamine, and on the average four of the five possible replaceable hydrogens will be involved in each thymonucleic acid—44 salt-like bondings in all. The protamine content of this composite molecule would be 37.25 per cent, and its theoretical molecular weight 21976. Allowing an absolute mass of 1.65×10^{-12} γγ per unit of molecular weight, a single such molecule must weigh 3.63×10^{-8} γγ, or approximately

$$\frac{1}{28000000} \gamma\gamma.$$

The species differences in the major composition of nuclei reside much more in the protein part and much less in the nucleic acid component. Thymonucleic acid is almost universally characteristic of the vertebrate series, although certain mammalian glands (e.g. the pancreas) yield related variants. (Levene and Bass, 1931.) The protein constituent of the nucleus may diverge widely in different tissues of the same species, and in the same organ of different species they appear to be identical only in related species or in representatives of closely related genera. (Kossel, 1928.) The entire chemical class protamine is limited, so far as known, to the ripe sperm of certain families of bony and ganoid fishes. The chemical entity

salmine seems to be shared by the Atlantic salmon and some of the Pacific salmons, representing kindred genera. (Yamagawa and Nishizawa, 1934.) Certain other Pacific salmons are suspected of carrying a slightly different protamine. The sperm of the tuna fish has a protamine nucleate much resembling that of salmon, but its protamine differs in containing at least one additional amino acid, tyrosine. In the common carp there seems to be a mixture of two protamines, in one of which lysine, which is no constituent of salmine, predominates over the arginine, while in the other the arginine predominates. The corresponding protamine in sturgeon sperm contains all three of the basic amino acids, arginine, histidine and lysine in such proportions that their sum comprises two-thirds of the total count of amino acids in the molecule. Illustrations of these variations among different families of fishes could be extended further from the literature.

In most animal nuclei other than the ripe sperm of certain fishes, the protein which combines with the nucleic acid is not protamine, but histone. Materials of this class have been reported in chromatin-rich glands, such as calf-thymus, in red blood corpuscles of birds, in the unripe testes of Rhine salmon, in spermatozoa of the cod, and of its relative the burbot (*Lota*), in ripe male organs of several echinoderms, etc. (Mathews, 1897; see also Leipert and Kurokawa, 1933.) These histones are proteins somewhat related to protamines, but with a much larger variety of amino acids, bespeaking a more complex total molecule. Their proportional content of basic amino acids is decidedly less, with the result that their molecule is less markedly basic than that of a protamine. One of the major distinctions of the histones is their digestibility by pepsin as well as by trypsin, while protamines are vulnerable to pancreatic juice but not to gastric digestion.

The histological staining methods by which chromatin is commonly recognized may be looked upon as direct chemical tests for acidic material anchored in insoluble form in the fixed tissues.

Unsatisfied phosphoric acidic bonds in the nucleic acid-protein salts combine either with the basic dye stuff or with the heavy metal of the mordant to produce the highly localized staining effect. In the absence of other insoluble acids this serves both as a confirmation of our conclusion that not all the 5 acidic bonds of the nucleic acid are covered by protein linkage, and as a beautiful demonstration of the localization of these incompletely neutralized nucleic acids in the structures known as chromosomes. But these stains are *per se* diagnostic only of insoluble acids anchored in the tissues, and the interpretation that they spot the nucleic acid is only permissible if it can be reasonably assumed that no other insoluble acids are on hand to participate in the reaction. For intranuclear structures this assumption is at least tentatively justified, although in less known extranuclear structures, it is rather dubious, and in certain cells definitely erroneous. Another inherent defect in the staining methods is the doubtful interpretation when they fail to give a good color. Many nuclei are scarcely touched by "nuclear" stains. The oft-made inference that these cells are nearly devoid of "chromatin," or of typical nucleic acids, may sometimes be correct, but biochemical writers have long recognized the more likely alternative that the nucleic acid has been completely and firmly neutralized by combination with a higher proportion of basic proteins. (Miescher and Schmiedeberg, 1896, p. 126, 149; Neumann, 1898.) It is worthy of note that nuclei showing this condition are sometimes found in cells that are ancestral to the sex cells, which must therefore be carriers of the entire hereditary material in its completeness. Is the histone nucleate omitted from the constitution of such a cell, or has it merely been rendered nonstainable by neutralizing the nucleic acid with a slight relative oversupply of the histone?

Caspersson (1936, 1937) has recently published an intensive study of nuclei, using microchemical methods, ultraviolet photography, digestive technics, etc. He used the giant chromosomes from insect salivary glands, and various other histological materials. The banding which is revealed by staining these chromosomes corresponds very closely to bands of nucleic acid as detected through the fact that nucleic acid is opaque to ultraviolet light of lengths from

2560 to 2750 Å. These bands are a protein-nucleic-acid combination, while the intervening zones are protein that contains no nucleic acid. In cells from other sources he reports a discrepancy between the staining reactions and the distribution of nucleic acid, since this is found both in basophilic and in certain acidophilic cytological structures. During mitosis the nucleic acid is, he reports, more abundant than at other stages, despite the fact that it is absent outside of the chromosomes while the cells divide.

Roughly speaking, there is good agreement between Caspersson's observations and the pictures produced by the Feulgen microchemical test for thymonucleic acid. The latter test rests upon a color reaction for desoxyribose. (Feulgen and Rossenbeck, 1924; Wyckoff, Ebeling, and Ter Louw, 1932.)

The mineral chemistry of nuclei is a subject which has come into much confusion, both as to the data and as to the interpretations. Macallum's belief (1926), that iron is abundantly present in an organic combination in the chromatin, and that the nucleus is essentially free from inorganic salts, is open to several serious reasons for doubt. Such ions as potassium and chlorine are so much more diffusible through dead membranes than are the reagents by which he tested for them, that when we find their precipitates accumulated at or just outside the nuclear membranes the observation will hardly preclude the possibility of a distribution of these ions within the nucleus previous to the cell's death.

Evidence regarding iron in the living chromosomes is complicated by the great avidity of nucleoprotein for inorganic iron, and by the resulting risk that this element will reach the chromosomes during the histological manipulations. (Gilson, 1892.) Unpublished observations by the present author show that even a very long treatment by Macallum's ammonium sulphide histological method generally fails to bring out any coloration of the chromatin, if the preparations have been kept rigorously free from all extraneous iron. But the sulphide reagent is microchemically speaking a sufficiently good solvent so that iron from external sources, such as rust-containing dust, is definitely transported by it into the chromosomes, causing them to develop a good iron-sulphide color. It is clear, then, that even when chromatin takes the stain in a preparation that has been kept free from the accidental introduction of iron, this does not give us any information about the *in vivo* location of the metal. Macallum's hematoxylin test for iron, being even more delicate than the sulphide and ferricyanide tests, is subject in just that much greater a degree to the difficulty that infinitesimal traces of foreign iron may give a spurious positive result. (Macallum, 1897; Dieterle, 1930.) Mühlmann (1928) refined this method by the use of a control slide which received a preliminary treatment with oxalic acid. Structures staining deep blue or blue-black must contain iron if the control slide shows them unstained. But even this can only be useful in chromosome studies if it be true that one can "unmask" the supposed nuclear iron from its supposed organic linkage without permitting it to shift its location.

Micro-chemical incineration tests made by Policard show that spermatozoan heads and many other nuclei yield an abundant colorless ash, as contrasted with the rust-yellow ash obtained from the cytoplasm of cells that are rich in iron. (Policard, 1933, 1934; Policard and Rojas, 1935.)

We judge, then, that chromatin can contain considerable mineral matter. The evidence does not indicate whether this consists of mineral salts, of organically bound material, or both. Iron is not a predominant element in nuclear ash. Indications are that Macallum's nuclear iron is, at least much of the time, an artefact, and that if there is any intrinsic iron in the chromosomes, it cannot be

abundant and cannot be brought out by Macallum's ammonium sulphide procedure.

From various of the findings thus far rehearsed it seems justifiable to infer that all but a trivial residue of the material of the salmon sperm consists of a substance, complex indeed, and chemically labile, but so monotonously homogeneous in its molecular constitution, and so devoid of special characteristics that we cannot avoid the feeling that what is most significant in the physical basis of heredity has quite escaped the chemical analysis (Koltzoff, 1928). Are we to find this significant something in the residual trifling quantities of unanalyzed organic substance, or shall we suppose that the most completely known and simplest of all natural protein compounds is the seat of specialized arrangements of its parts that endow it with the tremendous potentialities of the genetic units,—or must we now turn scientific pessimists and substitute a mystical for a scientific analysis? If we choose to credit the unanalyzed residue as the seat of all that is really crucial in the assembled genes, we must keep it in mind that in each spermatozoon this residue only constitutes about 3 per cent by dry weight, comprising in the case of sperm heads of the human size, scarcely 0.2γγ of dry substance, or in common units .000,000,000,2 mg. The corresponding residual matter in *Drosophila* must be 25- or 30-fold less still. The alternative that some hidden character of protamine nucleate may account for the genes is refuted when we find that earlier generations of germ cells in the salmon testicle possess no protamine whatever, but apparently a nucleic acid combination with an entirely different type of protein, belonging to the histones. Thus in addition to its inadequate diversification, the chromatin of salmon germ cells fails to have the chemical continuity that should distinguish the physical mechanism of heredity. Even the variable staining reactions of different germ cell generations serve to remind us that "chromatin" and "gene substance" are not synonymous. The large amount of genetically inert chromatin found in Y-chromosomes points to the same thought. It would be more nearly correct to argue that chromatin is the matrix in or on which the genes are located. (Miescher and Schmiedeberg, 1896, p. 149; Muller and Painter, 1932; Goldschmidt, 1927, p. 99.)

THE NUMBER AND SIZE OF THE GENES

Considering the minuteness of the spermatozoan head, it becomes of interest to ask how many genes it must be supposed to contain, and of how much material they are each composed. No thoroughly satisfactory mode of estimation is known, but the order of magnitude of the figures can be appraised by various methods.

In the common fruit-fly, *Drosophila melanogaster*, more than 400 loci of recessive mutations have been recognized, and the number is still increasing. Of these, upwards of 150 are of the type known as "sex-linked," viz. carried in the X-chromosome. (Morgan, 1922; Muller, 1922, 1929.) It scarcely needs to be mentioned that the total equipment of genes is certainly in excess, and in all probability very manyfold in excess, of those that have come under laboratory observation as the result of mutations.

The chromosome maps, which Morgan and his associates have made, symbolize in chart distances the relative intimacy of gene linkages within a chromosome versus the degree of freedom of cross-over. It is demonstrable that the distance intervening between genes is a major factor in the ease with which they become separated by cross-over into the other chromosome, although probably mere distance is

not the only factor. Thus the maps express a real linear relation, but doubtless with more or less distortion through local stretching and shrinking of the unit of length. If we assume, for simplicity's sake, that there are no such distortions in the map, then it appears that the genes lying closest together among those that have been studied statistically are separated by about $\frac{1}{5}\frac{1}{0}$ of the total length of one of the large chromosomes. (Morgan, 1922.) On this scale of linear units there might be in *Drosophila* about 1600 genes, as the haploid count. The elements of uncertainty render it hard to judge whether this is an over- or under-estimate.

Another method of approaching the problem is by treating statistically the frequency of repeat mutations. (Muller and Altenberg, 1919.) If genes are all equally subject to mutation, the frequency curve that has been found for repeating and non-repeating mutations within the number that have been recorded would correspond to the existence of about 2,000 genes in the haploid count. (Morgan, 1922.) It is probable that this is an underestimate, because the differences in mutability of different genes would distort the frequency curve in that direction.

The curious giant chromosomes found in the salivary gland cells of *Drosophila* have recently yielded valuable evidence upon the general structure of the genetic material. In these cells the strings of genes appear to have multiplied themselves not less than eightfold without the occurrence of fission, and furthermore the homologous chromosomes of the diploid count are joined side-by-side as if in a sort of synapsis, so that each patent chromosome is not less than a sixteen-fold structure throughout all its length. In addition, a vast growth of matrix material renders each chromosome 150 or more times as long as it is during the maturation divisions. (Painter, 1934.) When so stained as to bring out only the most acidic portions, a complex structure is revealed, which Bridges (1935) has attempted to interpret.

What appear to be transverse plates of "chromatin" can be resolved in many instances into sets of 16 spherical or clam-shaped vesicles of strongly staining acidic substance, each enclosing an unstained core. Zones which vary from this pattern seem to do so either by attenuation or by intensification and confluence of the original units. In some instances the confluence of one set of clam-shaped vesicles seems to result in a double chromatin plate, guarding both sides of a narrow, clear space. Bridges reports that if the center of each vesicle is the locus of a gene, the initial, haploid count of genes must lie between 2650 and 3540. The range of his uncertainty does not come from variation of the material, but from the difficulty in interpreting double bands.

Working with the same material, Muller and Prokofyeva (1935) made a detailed study of a few loci at the tip of the X-chromosome. They report that single gene translocations correspond to translocations of single chromomeres only in the case of the smallest chromomeres, and that the larger so-called chromomeres are really linear strings of several genes close together. Thus the individual genes in these giant chromosomes occupy particles of chromatin of a size just resolvable by visible light waves. A reappraisal of the chromatin particles, making due allowance for what they see as the composite structure of larger "chromomeres" leads them to multiply the previous estimate of the same giant chromosomes some two or three-fold; viz., to perhaps 5,000 or 10,000 units equivalent to genes.

An investigation by Gowen and Gay (1933) has been interpreted by them as leading to a startlingly high total count of genes.

Using Muller's statistical technique upon their own data from mutations induced by X-rays, they found the minimum figure 1975 for loci of visible, viable mutations, agreeing almost exactly with Muller's minimum of 2,000. But they found in addition to this that dominant lethal "mutations" were 5.5 times as frequent as visible viable mutations, and recessive lethal alterations 7.3 times as frequent. If all of these represent separate gene loci, the total count would be 13.8 times as great as heretofore supposed, or a haploid minimum of more than 27,000 loci. Recognizing, however, that there is likelihood of a great overlap among these three categories, Gowen and Gay suggest that the most numerous single category be used as the basis of an estimate,

and hence that separate genes may be tentatively judged to be 7.3 times as numerous as hitherto supposed, or in their own figures approximately 14,380 for the haploid count in *Drosophila*.

It should be remembered, however, that the high ratio of lethal changes is capable of the alternative interpretation that any one gene when subjected to X-rays may show various alterations, and that among these the lethal alterations are several-fold the most numerous.

In this connection Patterson (1932) studied a few selected loci in *Drosophila*, and reached the result that 87.5 per cent of the X-ray changes occurring at these loci and detectable by his methods are recessive lethal, and 12.5 per cent are visible viable mutations. Data of this kind will need to be increased before they can be used with much statistical accuracy.

However, if we assume that Patterson's ratio of 87.5 per cent lethals is more or less approximated among gene alterations in general, it will follow that the 1975 genes which have been indicated to account for visible viable effects would also be responsible for $\frac{87.5}{12.5} \times 1975$, or 13,825 recessive lethal effects out of the 14,380 to be accounted for, and that the remaining 555 recessive lethal effects, if they are due to gene modifications at all, cannot be cited as representing more than $\frac{12.5}{87.5} \times 555$, or 79 additional genes, bringing the required minimum up to 2,054. The implication would be that these additional 79 represent nothing more than the fluctuations of an inadequate statistical series.

We conclude that in the light of Patterson's ratio, the statistics of recessive lethal effects do not alter our previous estimate for the minimum count of genes in *Drosophila*.

The aggregate length of the chromosomes carrying the haploid supply of genes in the second spermatocyte metaphase of *Drosophila* is about 7.5 μ, so that by Muller's earlier minimum figure (2,000) they must contain not less than 267 genes for each μ of chromosome length, or 1 gene for each 3.75 mμ of the chromosomes. If they are spherical, this would mean a volume of 27.6 cu.mμ. The minimum count estimated by Bridges (2,650 genes) would allot one gene to each 2.94 mμ. Again, Muller and Prokofyeva's figures would call for 1 gene in each 1.5 mμ of these metaphase chromosomes. However, it is argued on microscopic evidence that the chromosomes at this stage have a coiled structure, twisting alternately for short distances in right-hand and left-hand spirals, so that the effective length of the string of genes may be quite a number of times the straight length of the compacted chromosomes. Since the chromosome must be able to split longitudinally into perfect halves, there is presumably a limit to the possible degree of spiraling.

For an earlier elongated thin-thread stage of the nuclear transformation, in which there can be no suspicion of a really close spiral, but in which it is easily possible that the gene particles may be strung along with interspaces, Morgan found (1922) that on the basis of 2,000 genes to the haploid count, occupying 40μ of effective length, there would be approximately 50 genes to each μ of chromosome thread, giving a maximum limit of 20 mμ length of thread per average gene at this state (Muller, 1922, 1929).

If each space of this size is occupied by a spherical gene, these spheres would need to average 4,190 cu.mμ or less in volume, and their total content in a haploid cell could not exceed .00838 cu.μ. Or if the genetic material is better represented by 3,540 spherical beads in a 40μ string, the average diameter could not exceed 11.3 mμ, with the average volume of their individual spheres approaching a top limit of 755 cu.mμ, and their aggregate volume not over .00267 cu.μ per haploid germ cell. Since a sperm head of *Drosophila* has a size of about 0.53 cu.μ, the value .00838 would represent 1.58 per cent of the estimated volume of a sperm head, and .00267 would represent 0.50 per cent in terms of volume. Percentages higher than these are only possible if the transverse dimen-

sions of the gene are greater than the dimension longitudinal to the string—a possible situation upon which we have no evidence, either positive or negative.

From another angle of approach it has been suggested further by Gowen and Gay (1933) that the amount of the gene material can be appraised by mathematical analysis of the effect of X-ray treatment, in terms of quantum relationships.

They assume that every quantum of energy withdrawn from the radiation during passage through the sperm head will result in the radical alteration of the organic molecule within which it was discharged. If we analyze their data we find that an average of 4.4 per cent of the quanta discharged (i.e. 5.5 per cent in the series with copper X-rays, 3.3 per cent with chromium X-rays) produce genetic results, if we include all the lethal and non-lethal varieties of effect. The figures run: Dominant lethal (av.) 1.75 per cent; recessive lethal, 4/3 × dominant lethal, = 2.33 per cent; visible non-lethal, $\frac{1}{5.5} \times$ dominant lethal = 0.32 per cent; ∴ total of identified mutation-sensitive and any other lethal-sensitive substance = 1.75 + 2.33 + 0.32 = 4.4 per cent of the sperm head. The remainder (95.6 per cent) is judged not to be mutation-sensitive, hence to be inert matrix.

The quantities and ratios given above are as stated by Gowen and Gay, but rearranged by ourselves for this presentation.

Gowen and Gay have proposed the tentative hypothesis that this target of sensitivity corresponds to the crucial gene substance.

In that case the total mass of gene substance in the sperm head would approximate .044 × .53 = .0233 cu.μ, in terms of the killed and stained volume. From this it would follow that the average size of the single gene would be

$$\frac{.0233}{\text{total number of genes}}$$

viz. .0000117 cu.μ or 11700 cu.mμ each, if their frequency is 2,000; or on the basis of 3,540 genes, given above as an alternative, the measure would be .00000658 cu.μ, or 6,580 cu.mμ. On the basis of the data presented by Gowen and Gay we are unable to agree to the validity of their estimate of 1.0×10^{-18} cu.cm. (equivalent to 1,000 cu.mμ) since it appears to us that the manner of calculation carries the implication which they themselves reject, of a total gene count in excess of 27,000. Nor is it apparent within the abbreviated limits of their published calculations that they really have three appraisals of the gene size based on sufficiently separate experiments to stand as mutually independent determinations.

The above calculations are open to the more general limitation that gene alteration is not the only way in which a quantum of X-ray energy can affect the chromosomes (Stadler, 1932.) In plant studies a very large share of the cases studied show translocations of appreciable portions of the chromosomes, alterations, that is, which may well be referable to damage of the supporting structures within which the genes are located. It appears from Patterson's test of this feature that in *Drosophila* a rather sizeable minority of the lethal effects may very well be of this nature, and in that case there is nothing in these experiments to preclude a somewhat smaller estimate of the total number of genes, and of the percentage of the chromosomal substance which they comprise.

A new form of tentative calculation of the gene size in *Drosophila* has recently been made by Muller (1935), by using the following assumptions:

In ordinary chromosomes the chromonema threads are conceded to be coiled. The giant chromosomes of the salivary cells appear to have them uncoiled. The X-chromosome has, in this case, a chromonema 200 μ long, of which it is known that only two-thirds—133 μ—can be genetically active (Muller and Painter, 1932.) Since Muller's present figures allow about 1000 genes to this chromosome, his estimate brings an average of 8 genes per μ in what is looked upon as the active portion of the chromonema. (Muller and Prokofyeva, 1935.) Let us assume that the oögonial chromonemata have the same dimensions as those in salivary cells, only disposed of in a spiral form; then if the entire oögonial chromonema of this chromosome were uncoiled to a length of 200 μ, the total bulk of this chromosome could only furnish material for a cylindrical thread this long and .02 μ in diameter. Or if the 200 μ should be drawn as a geometrical spiral line

upon the outer surface of the oögonial chromosome, the laps of the spiral would be spaced at intervals .044 μ apart. So on the basis of the assumptions with which he started, he proposes that genes are not more than some 20 to 40 mμ in transverse diameter, but that on account of heavy spiraling there is longitudinal room on the chromonemata for the genes to be as much as 125 mμ long, or spaced with that large an average interval between their centers. The size of gene which would fill this elongated space is to be looked upon as over-shooting the valid maximum, in-as-much as it assigns 100 per cent of the mass of the active segments of the chromosome to the actual gene substance.

Looking through all these estimates, we are led to a first approximation that the volume of an average gene lies between 28.6 and 4,190 cu.mμ. The larger of these figures cannot be exceeded very heavily for the reason that such large genes would preempt too large a proportion of the chromosomal mass, and leave over too little to be the containing matrix. Judging by the second spermatocyte chromosomes, this maximum is a substantial overestimate, as it seems hardly credible that those chromosomes are sufficiently spiraled to take care of 267 such large particles to the linear μ.

The minimum size reasonable for a gene can be checked upon by the assumption that we should not suppose it to fall below the size of an ordinary protein molecule. Ovalbumin, which counts as a relatively simple protein, has been studied by several techniques, and its molecular size appraised. (Calvery, 1932.)

By count of the amino acids contained, its molecular weight should be approximately 34,000 (i.e. $\frac{1}{17800000}$ $\gamma\gamma$) or a small integral multiple of this amount. By osmotic pressure it has been estimated at roughly 36,000. (Burk and Greenburg, 1930; see also Marrack and Hewitt, 1929.) Ultra-centrifugation indicates for it a molecular weight of 34,500 $\pm$ 1000, a bulk corresponding to a sphere 4.34 mμ in diameter and a specific gravity of about 1.45. (Svedberg and Nichols, 1926; Nichols, 1930; Svedberg, 1931.) The ovalbumin particles are reported to be approximately spherical when in solution, with a spherical volume, as calculated from the above diameter, of 39.2 cu.mμ. Surface tension tests indicate that under surface conditions the particles measure 3.08 $\times$ 3.08 $\times$ 4.17 mμ, which would make them enclosable in a rectangular solid having 39.6 cu.mμ. (duNoüy, 1925.) At the face value of this comparison it appears reasonable to infer that a gene should not be expected to drop below a total volume of 39 cu.mμ. But if we accept the recently proposed lamellar structure for these "globular" protein particles, it is possible that the minimum adequately individualized particle consists of fewer lamellae, and that the smallest reasonable size for a gene would be a flat disk having major diameters of 3 or 4 mμ, and in the other direction perhaps only 1 or 2 mμ. However, opposite faces of protein lamellae are strongly polar, and inasmuch as the gene chain is not longitudinally polar, we are not permitted to picture this chain as a column of protein lamellae stacked up like coins. If 3.08 mμ is the minimum linear space that each gene must occupy, the maximum count in the second spermatocyte of *Drosophila*, with its 40 μ of chromatin thread, cannot exceed 13,000. This is an extreme minimum size and maximum count, there being, as we have seen, no positive evidence favoring any larger number than 5000 in the haploid count in *Drosophila*.

The question may be asked whether particles as small as we have described are adequate for the functions that a gene must perform, and here once more comparison is in order. It is not entirely relevant that some of the hormones have outstandingly small molecular weights, as their significant effects depend entirely on their stimulation of living cells, under such conditions that the complexity of the result seems to be easily referable to the complexcity of the cells receiving the stimulus. Enzymes present a better comparison, because of their frequently great specificity, because of their wonderful power to bring about transformations that could not have been predicted *a priori*, because they can work without the aid of additional biological complexities, such as are necessary for the hormones, and finally because they are heat-labile, which we may presume the genes also to

be. Several of the enzymes show indications of a protein constitution, or of linkage to protein, and the size of their particles or molecules may be inferred to be of the order of magnitude of the proteins. In the case of pepsin, a crystalline preparation which is believed to represent the pure enzyme gave evidence (under ultracentrifugation) of having a molecular weight between 34,400 and 36,600, i.e. quite comparable to crystallized ovalbumin. (Philpot and Eriksson, 1933.)

Viruses, such as the bacteriophages and the active principles of plant mosaic diseases, are particularly tempting for a comparison because they furnish a parallel that comes nearer to true biological conditions. Indeed Gowen and Price (1936) have shown that genes and viruses are much alike in their susceptibility to X-ray irradiation, and McKinney (1937) has shown that they are similar in their propensity for mutation. In drawing a further comparison we must keep in mind that a virus may very possibly be an entity one stage higher than the gene, since it has sufficient biological autonomy to invade successive host organisms, and even to undergo progressive adaptation to taxonomic differences in the host. Unfortunately, the principal methods for measuring ultramicroscopic particles are either doubtfully accurate or very difficult when applied to bacteriophage. Their supposed diffusion constant seems to point to a diameter of about 12 mμ.

The closest grained filters through which they can pass are believed to have maximum pores of 300 to 400 mμ, which on the usual basis would mean a particle diameter presumably between 20 mμ and 50 mμ. (Krueger, 1936.) When subjected to ultracentrifugation one bacteriophage seemed to consist of particles with a specific gravity of 1.11 to 1.14 and a diameter of 79 mμ to 90 mμ, a size equivalent to that of 8,000 or 10,000 molecules of ovalbumin. (See Bechold, 1934; Thornberry, 1935b.) On the other hand a more recent determination made upon another bacteriophage leads to an apparent particle diameter of 11 mμ, or a size only equal to some 16 or 18 ovalbumin molecules. The smaller of these estimates are well within the possible size-range of the genes. The larger appraisals correspond more nearly to the aggregate size of a gene plus its proportionate quota of surrounding chromatin, for if the 530,000,000 cu.mμ (i.e. 0.53 cu.μ) of a *Drosophila* spermatozoon should be divided into 2,000 equal spheres, they would each measure 79.7 mμ in diameter.

The recently accomplished purification of the virus of the tobacco mosaic disease gives opportunity for even more cogent comparisons. (Stanley, 1935a; 1935b; 1937a; 1937b.) This is a crystallizable substance, showing the composition of a nucleoprotein and endowed with powers of enzymatic autosynthesis. (Bawden and Pirie, 1937.)

It yields 16.5 per cent–16.7 per cent nitrogen, has an ash content of about 1 per cent, sulphur 0.26 per cent, phosphorus 0.51 per cent, and gives the biuret test and color tests for the amino acids tyrosine and tryptophane. A temperature of 94° coagulates and inactivates it. Combined with relatively basic proteins (globin, trypsin, trypsinogen, clupein) it is reversibly precipitated, thereby suspending its infectivity. In this reaction its apparent acidic reaction weight is about 4000. If the protein portion is separated from the nucleic acid it becomes pepsin-digestible. The analyses indicate the presence of a tetra-nucleotid similar to yeast nucleic acid, but not stereoidentical. This comprises 5.2 per cent and the protein 94.8 per cent.

The diameter of the tobacco virus particle is stated to vary heavily with changes of the pH and other influences. (Eriksson-Quensel and Svedberg, 1936.) Waugh and Vinson (1932), reported an active preparation with an apparent particle diameter not higher than 5 mμ. Thornberry (1935a) reported an active solution of this virus in which the particles were found to measure about 11 mμ judged by their diffusion constant. According to Bechold (1934) centrifugation of a solution of tobacco virus gave evidence that the particle-diameter was about 50 mμ. Dimensions almost this large are indicated by Stanley's estimate that the molecular weight is 17,000,000, or equivalent to about 500 ovalbumin molecules (Stanley 1937a and b). Bawden and Pirie argue that in its native state the unit particles are in the shape of plates or short rods about 17 mμ in diameter. In this connection it is to be noted that Clark (1938) ob-

served in the dry gel of tobacco virus a fundamental spacing of 15.2 mμ which changed to 21 mμ in the wet gel, and came into the range of 30 to 47 mμ in the liquid condition.

It appears, then, that such viruses as the tobacco mosaic and the bacteriophages, which may conceivably rank biologically one stage higher than the genes, are sufficiently minute to stand in harmony with the provisional conclusions concerning the dimensions of genes.

It is by no means necessary to suppose that all genes are equally small, or that in some phyla they may not far exceed the upper limit of size given by the above calculation made from the germ cells of insects. In various Liliaceae Belling (1931) observed an extremely minute particle at the core of each chromomere, which he believed to be the gene itself. He found from 1400 to 2500 of these particles per cell, according to the species—a very reasonable total number. They take the nuclear stains with especial intensity. Any experimental data bearing upon Belling's suggestion would have the greatest interest, especially as it would be extraordinarily gratifying to biochemists to learn the staining and other microchemical characteristics of plant genes, and to compare them with the gene-like structures in the salivary cells of insects.

In summary, the total haploid number of genes in a *Drosophila* germ cell having an X-chromosome must be not less than 2,000. No explicit evidence has been found in favor of numbers much exceeding 5000, and there are definite reasons unfavorable to a count greater than 13,000. The principal linear dimensions of any individual gene should not be accounted less than the diameter of a "globular" ovalbumin molecule (i.e. 3 or 4 mμ). Their shape remains thus far indeterminate, e.g. whether spherical, discoidal, etc. In *Drosophila* they cannot exceed 4,190 cu.mμ in average size or a sphere 20 mμ in diameter, representing a bulk equal to 107 ovalbumin molecules. Their true average size is probably well within these extremes. In other organisms the size may exceed the *Drosophila* maximum, but it cannot well drop below the cited minimum.

The genus *Homo* has characteristically six times as many chromosomes as *Drosophila*, with an average length of individual chromosomes during most stages somewhat greater in *Homo*. If the average count of genes per chromosome is comparable in the two species, this would allow for man a haploid quota lying somewhere between 12,000 and 78,000 genes. Another mode of comparison depends on the second spermatocytes, for which it is estimated that Wieman's drawings (1917) indicate 12.4 μ as the aggregate length of the 12 chromosomes, which seem here to be duplex structures, making 24.8 μ the length in simplex terms, or 3.3 times the corresponding length in *Drosophila*. If there are comparable numbers of genes per μ of length in the two species, this would give for man a haploid gene count between 6600 and 43,000. Either of these figures seems surprisingly small when we consider the complexities of the human organism, or when we consider that the largest figure gives a diploid count barely in excess of one's theoretical count of ancestors seventeen generations ago.

It has already been mentioned that the human spermatozoon cannot be supposed to carry more than about 0.2 γγ of crucial gene material. Since this figure lies completely outside the scope of common experience, we venture the further comment that it requires on this basis not less than 5 thousand million spermatozoa (a number greater than the world's human population) to carry one milligram of crucial genetic substance.

APPLICATION OF THE ENZYME AND HORMONE CONCEPTS

The nature of the regulation exerted by genes has most often been described as enzymatic. This thought is founded on several considerations. In the first place the disproportion between ultraminute regulatory particles and grossly visible biochemical outcome scarcely permits any other hypothesis than enzymatic catalysis. Then again many Mendelian characters are recognizedly due to loss, alteration, or change in the quantity of certain known enzymes, as, for example, the oxydases that regulate the formation of pigments. (Scott-Moncrieff, 1937.) Also there is the long-standing observation that breakdown of the nuclear membrane, as at the start of the cleavage of the egg, has the effect of touching off a burst of enzymatic activity in the cytoplasm, either from the release of active principles out of the nucleus or from their sudden generation in consequence of the inflow of nuclear substance. Further in harmony with this concept is the observation that embryonic cells, as well as cell masses that regenerate amputated parts, develop in perpetual interrelation, as if influenced by a steady exchange of more or less diffusable regulatory substances.

Substances of the nature of hormones, having, that is, a drug-like potency with effects specific to the type of cells upon which they are working, may also be invoked, as they would conform to many aspects of the experimental observations. (Troland, 1917.) Goldschmidt (1927) in particular has emphasized the appropriateness of supposing a regulation carried out through hormones, emanating from the gene and working sometimes at intracellular and sometimes at intercellular ranges. Such hypothetical hormones may be looked upon as end-products of enzymatic actions set up by the respective genes. Without using this term, Ekman (1930) favors the same fundamental thought, arguing that the cytoplasm (and not the nucleus) is the regular seat of synthesis for the more familiar enzymes.

Both enzymes and hormones are conditioned in their action by the nature of the medium in which they lie. A hormone may produce a dozen different effects in a dozen different tissue types, and in other tissues perhaps no effect at all. Enzymes are notoriously specific as regards substrate, co-enzymes, anti-enzymes, and the like. Thus both enzymes and hormones allow ample room for the requirement that one set of genes shall regulate the Entwicklungsmechanik variously in different parts of the developing organism.

The importance of enzyme regulation is not limited to the formative stages of an organism, and if genes are enzyme regulators we ought to find indications that they function throughout life. In accord with this, it is well known that after intensive activity of any adult gland, nerve, or muscle tissue, the histological evidences of nuclear fatigue are very pronounced. (Hodge, 1892; Dolley, 1909.) If carried to the limit there even results a picture of impoverishment of the nuclear substance, almost to the point of total destruction.

The raw materials, out of which the genes construct the active substances (enzymes or hormones) that they send out into the cell, must be provided by the materials observable within cell nuclei. The most abundant of these is usually histone nucleate. Complex lipins may also play a significant rôle, to judge by modern studies of hormones and vitamines. Spermatozoa and other nuclei undoubtedly possess important lipins, but the actual percentages are not high, and as yet our information about them is very scant. Another possibility is that spare molecules of the gene substance itself may float free

and function as a hormone. (Haldane, 1937.)

As a corollary to the thesis that genes exercise their influence by way of hormones it is theoretically conceivable that the converse relationship may also hold good, and that the gene may be alterable through hormonal or humoral influences from other portions of the body. Some such effect is conceivable either as an alteration of the future reproductive cells, or as a modification of the internal potencies of corresponding genes in different organs of the body. The latter proposition has never been put to an experimental test. The tentative reaction of most scientists is to take the same attitude toward it that is taken toward the question of humoral modification of the traits of offspring, for which the following evidence is the most cogent available.

If a newly fertilized angora rabbit ovum is transferred into the oviduct of a rabbit belonging to the Belgian breed, the resulting offspring shows no trace of genetic influence from the foster-mother, but retains all the angora characters, even to displaying certain distinctive reflexes. (Heape, 1890, 1897.) A still more drastic experiment is to provide a young spayed guinea pig with ovaries from a source representing a different hair color. (Castle and Phillips, 1911.) Under these conditions an albino foster-mother has no slightest diluting effect either on a deeply colored pelt or on one that is already a pale cream (Castle, 1911).

AUTOCATALYSIS

The process by which a gene brings about its own reduplication has been referred to by various authors as autocatalysis. (Muller, 1922; Koltzoff, 1928.) From the mathematician's standpoint the concept of autocatalysis is very precise, but as a biological concept it is quite the reverse. Whenever any reaction, event, or active substance works in a manner to bring forth more of the same reaction, event or active substance, the effect counts as autocatalytic. Processes as diverse as the hardening of linseed oil, a forest fire, and the normal increase of human populations, are all perfectly good examples of autocatalysis, and as such conform to the mathematical rules when the external conditions are held constant. The autocatalysis of genes, which might better be styled autosynthesis, belongs to a special class of such phenomena, and challenges special consideration. The action is in many ways comparable to that of the intracellular synthetic enzymes. It is generally accepted, for example, that synthesis of proteins in the living cell is carried out by means of protease enzymes, which probably are also themselves proteins. Recent literature has, for example, called attention to papain as a protein-building enzyme that is reported to be itself a protein. (Bergmann and Niemann, 1937; Bells and Lineweaver 1937.) Similarly the gene must be an enzymatic particle, most probably protein in nature, or at least protein-like in its framework. One of its enzymatic traits must be to condition the synthesis of its own kind of gene substance. In this respect it is strictly comparable to the viruses, such as bacteriophage and the crystallizable tobacco mosaic virus. The substrate for this reaction appears to be the mixture of protamine or histone nucleate and cell sap extractives that normally environ the genes. The startling situation is that among the thousands of different genes present in any one cell, each severally has the unique potency for producing new molecules that duplicate its own peculiar constitution. Furthermore, when a chemical alteration is suffered through some physical disturbance (mutation) we

have at once not merely a new gene, differing from its antecedent gene by some slight item of chemical constitution, but at the same instant there springs up in it the new potentiality to activate hereafter the synthesis of molecules of this same new variety. (Muller, 1922.)

We are not aware that any other cases outside of genes and viruses have been reported in the field of chemical catalysis, in which there is such perfect specificity combined with what might be called the flexible feature, that any slight alteration in the chemical constitution of the activator molecule leads at once to an exactly duplicate alteration in the synthesis that is induced. It is not necessary, however, to regard this metaphysically as a "vitalistic" manifestation, because in another chemical field—crystalography—there is a perfectly comparable example of selective action (Troland, 1917), molecules being able to join a particular crystal only if they have or take on a structural configuration exactly like those that already compose the crystal. We may say, then, that the autocatalysis of genes must represent a reaction mechanics after the manner of the protein-synthesizing enzymes, combined with a regulative feature in some way akin to what is observable in the forces that regulate the formation of crystals, with their molecular specificity. Koltzoff (1928) proposes, for theoretical reasons, that it is a general trait of the unspoiled proteins of the living cell to tend to catalyse the formation of duplicate molecules to their own. If this hypothesis is verified, then genes and viruses become special cases of a much more wide-spread type of chemical activity.

The peculiar dead-stop which this process suffers as soon as the number of gene molecules has been doubled is another feature that could easily be related to some sort of crystalographic or aggregational limitation. There is, at least, no evidence that it is due to exhaustion of material. We note the suggestive fact that the same structures which evince this autocatalytic dead-stop upon reaching the duplex condition show the further peculiarity during the maturation divisions, of pairing off, like-to-like, with their counterparts in the homologous chromosome. Thus there seems to be something special about the duplex condition in genes that awaits further elucidation.

Life in general has been described as autocatalytic. But it should be noted that self-propagation of cellular or multicellular structures is essentially a derived attribute springing from the autocatalytic and other catalytic activities of the included genes, conjoined, possibly, with the autocatalytic propensity of the cellular proteins. Experimental studies indicate that outside of genes the only visible formed structures with a comparable degree of self-propagating power are the plastids of plant cells. (Muller, 1922; van Wisselingh, 1920; Ekman, 1930; Renner, 1934.) It seems scientifically superfluous, then, to postulate any additional reproductive potentialities for the larger units of life.

HOW FAR CAN CHEMISTRY PICTURE A GENE?

Our study of the chemistry of the germ-cell nucleus did not reveal the material of the genes, but only the matrix in which they lie, from which their substance must be compounded. From this study of the material background of gene construction, we may infer that the chemical framework of the genes must be protein in nature, with a wealth of the more basic amino acids, and that also they may well contain substances derived from nucleic acid. Insect salivary cells give evidence of a concentration of nucleic acid at or around the locus of the gene, but there is no clear basis on which to determine

whether nucleic acid enters into the gene constitution, or whether it serves simply as a mechanical matrix or as a metabolic source for smaller structural units, such as purines and pyrimidine rings.

There is such a high degree of congruity in the behavior of all genes that we must allow to their protein molecules a very strong family resemblance. We do not know whether it is essentially protamine, or histone, or a member of some quite different division of the proteins. Their structure must, however, be vastly more complex than any protamine that has been studied, so great, indeed, that there is practically no limit to the possible number of new gene substances that can exist within the bounds of their chemical family; just as, for example, there seems to be no limit to the number of members in the hemoglobin family of proteins.

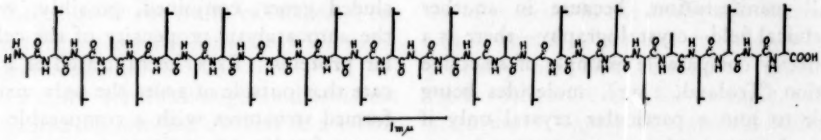


FIG. 1. MOLECULE OF CLUPEINE, OR HERRING PROTAMINE, ACCORDING TO LINDERSTRØM-LANG
Long vertical strokes represent arginine residues; shorter vertical strokes, residues of other amino acids

The molecule characterizing a specific gene must have a very definite chemical and space configuration, which remains perfectly constant except during the process of mutation. Theoretically any slightest change of the molecule must count as a mutation.

During the last few years much has been learned about the internal atomic pattern upon which proteins are constructed. (Jordan-Lloyd, 1937; Linderstrøm-Lang, 1935.) According to X-ray and related studies there appear to be four major types of protein molecule, as follows:

(1) The linear polypeptide, as exemplified by clupein, (See Fig. 1) the protamine from herring spermatozia; (2) The fibrous proteins (Astbury and Woods, 1933), (See Fig. 2) having a characteristic laminated grid pattern that can be analyzed by X-ray; (Bernal and Crowfoot, 1934; Crowfoot, 1935; Wyckoff and Corey, 1936). (3) The colloidally dissolved proteins with massive, more or less "spherical" molecules, in which a laminated internal structure may be detected; (Clark and Shenk, 1937; Clark, 1938.) (4) A possible polyhedral type of large molecules, formed by a different arrangement of the lamellae. (Wrinch, 1937b.) Other patterns than these four are not necessarily excluded. In both the non-fibrous and the fibrous laminated proteins the principal plane of each lamella is occupied by the carbonyls, α-carbons and α-amino groups of the peptide linkages, apparently bound into hexagons, very nearly after the manner that Abderhalden long advocated. The remainders of the constituent amino acids project away from the principal plane like the nap of a velvet. The spacing between the principal planes of the lamellae approximates 1 mμ or 10 Å.

X-ray analysis of the fibrous proteins (e.g. keratin) leads to the conclusion that their lamellae have an elongated hexagonal ground pattern. (Astbury and Woods, 1933.) This design is one that is geometrically equally possible in relatively small protein molecules and in fibrous masses of indefinite extent. Figure 2 represents a limited grid of this fibrous type, redrawn from Astbury's and Woods' diagram for keratin, making use of considerations brought up by Wrinch (1936b) and by Rainey (1937). The projecting "nap" of amino-acid residues lies on both sides of the principal plane.

The lattice-work found in hydrated and globular protein molecules has been examined in certain cases.

Astbury and Lomax (1935) describe a three-dimensional pattern built by laying straight polypep-

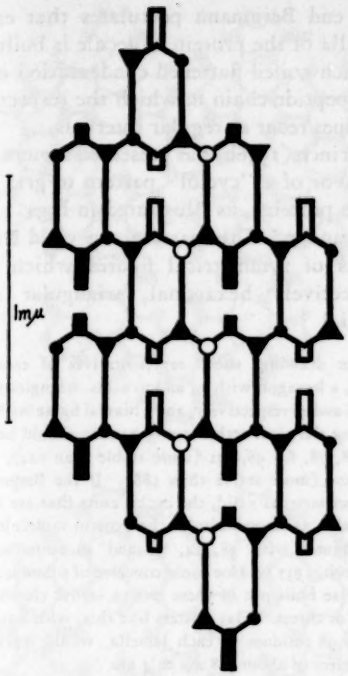


FIG. 2. PATTERN OF A FIBROUS PROTEIN LAMELLA, KERATIN TYPE, ESSENTIALLY AFTER ASTBURY AND WOODS

Symbols

- Amino-acid residue, pointing obliquely out and up.
- Amino-acid residue, pointing up.
- Amino-acid residue, pointing obliquely out and down.
- Amino-acid residue, pointing down.
- NH group.
- N—without H.
- C=O group.
- C—OH hydroxyl pointing up.
- C—OH hydroxyl pointing down.

tide chains side by side. The polypeptides are judged to carry one amino acid residue for each .35 mμ of their length, the residues projecting alternately on opposite sides of the chain. In the plane of the residues these polypeptides are conceived to engage each other through the residues, being held apart at a distance of 1 mμ or 10 Å between chains. At right angles to this plane the chains are repeated at a grid spacing of .45 mμ.

Non-fibrous proteins can be found with molecular weights all the way from a few thousand to several million, but a molecular weight of 34,500 ± or integer multiples of this occur with such persistent frequency in the most diverse proteins as to demand especial attention. "Spherical" molecules of this size show diameters of 3.5 mμ to 4.2 mμ, indicating a thickness equivalent to four (or possibly three) lamellae. If the amino-acid residues in these proteins vary in average weight from 120 down to 114, it would follow (on the basis of four lamellae) that there must be some especially stable configuration of lamellae occurring at a molecule size in the range of 280 to 320 amino acids.

Bergmann (1937) contends that this Svedberg unit of protein molecular weights (roughly 34,500 ±1000) is due to a fixed normal content of 288 amino acids, or an exact multiple of this, in the native proteins. This number may be expressed as $2^5 \times 3^2$. He believes that in general the number of residues of any one amino acid present in the total molecule is also such that the number can be given the form $2^n \times 3^m$, where n and m are integers (or zero), and that in the main the ratio of any one amino acid is a fraction $\frac{1}{2^n \times 3^m}$ of the whole count of residues. That is, each amino acid will represent something like $\frac{1}{72}$, $\frac{1}{32}$, $\frac{1}{24}$, $\frac{1}{18}$, $\frac{1}{4}$ or some similar fraction of the entire number. To account for such a frequency-pattern, one can hardly suppose otherwise than that there is a precise, rhythmic internal structure to the large molecule, and to

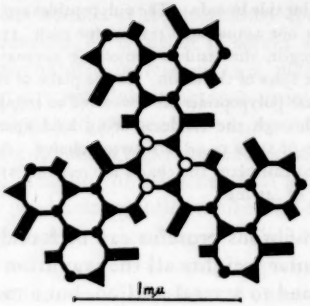


FIG. 3

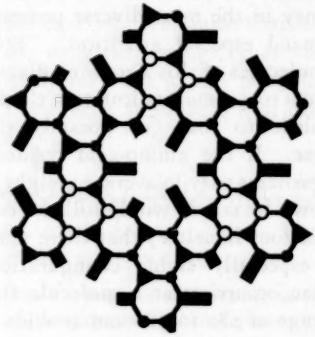


FIG. 4

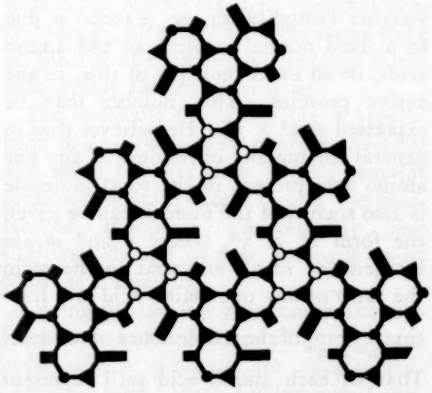


FIG. 5

FIGS. 3, 4 AND 5. EXAMPLES OF SUPPOSED CYCLOL CONFIGURATION, WITH 18, 24 AND 36 AMINO ACIDS EACH

Symbols are the same as in Fig. 2

this end Bergmann postulates that each lamella of the protein molecule is built as a much coiled flattened condensation of a polypeptide chain in which the respective residues recur at regular intervals.

Wrinch (1936b) has presented arguments in favor of a "cyclol" pattern of grid for these proteins, as illustrated in Figs. 3, 4, 5, 6 and 7. This pattern can yield three series of symmetrical figures which are respectively hexagonal, triangular and biaxial.

Our drawings show representatives of each of these, a hexagon with 24 amino acids, triangles with 18, 36 and 48 respectively, and a biaxial figure with 72. Among the most stable configurations should be 24, 38, 58, 78, 84, 98, 142 (more stable than 144), 180, and 276 (more stable than 288). If the Bergmann number series is valid, the cyclol units that are most available as lesser units in the protein molecule are the figures with 18, 24, 36 and 48 amino acids (Wrinch, 1937). One could conceive of submolecular lamellae built out of these groups in flat clusters of fours or threes. Flat clusters like this, with a size of 72 to 98 residues to each lamella, would represent diameters of about 2.8 mμ to 4 mμ.

Due to the laevo-configuration of the α-carbons the cyclol pattern brings all the "nap" of the "velvet" on one side of the principal plane. (Jordan-Lloyd, 1932.) Our figures illustrate this point, and represent the absolute orientation as worked out by Rainey (1937). The other face of the lamella is free from bulky obstructions, and is provided with numerous hydroxyls produced by the shift of hydrogens onto the carbonyl groups. Such a free face should be capable of specialized contact reactions with other compounds possessing condensed hexagonal groupings, such as vitamin-D, sex hormones, carcinogenic hydrocarbons, and various alkaloids.

Clark and Shenk (1937) discuss another possible variant of lamellar protein, which was first propounded by Astbury and Woods (1933) and which they believe

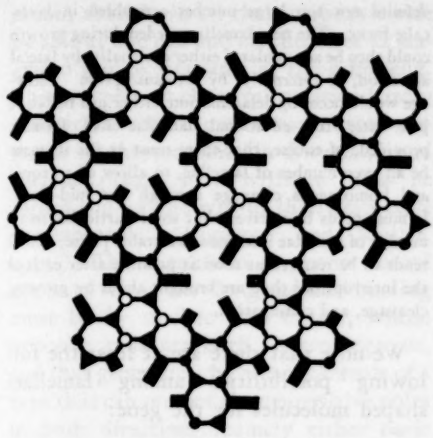


FIG. 6

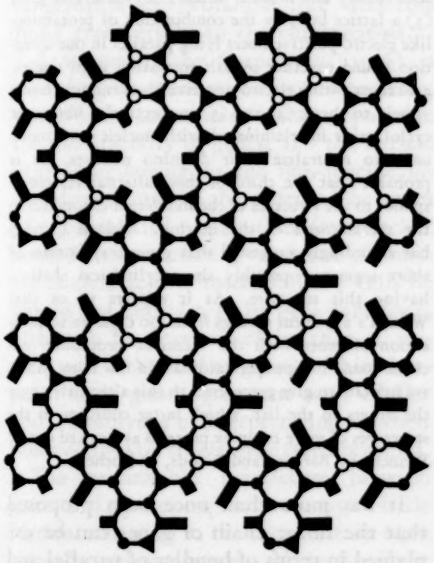


FIG. 7

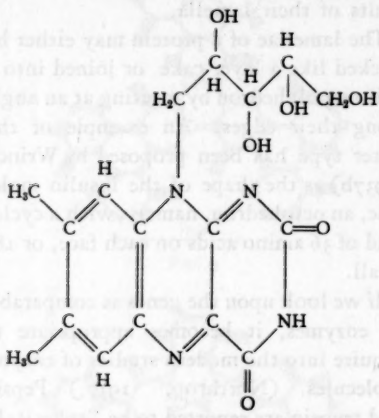
FIGS. 6 AND 7. EXAMPLES OF SUPPOSED CYCLOL CONFIGURATION OF PROTEIN LAMELLAE, CARRYING 48 AND 72 AMINO ACIDS EACH

comes near the true condition of egg albumin. In this the fundamental spacing has much in common with fibrous proteins, but the polypeptide strands are thrown into a serpentine, within the limits of their lamella.

The lamellae of a protein may either be stacked like a layer-cake, or joined into a hollow polyhedron by meeting at an angle along their edges. An example of the latter type has been proposed by Wrinch (1937b) as the shape of the insulin molecule, an octohedron, namely, with a cyclol grid of 36 amino acids on each face, or 288 in all.

If we look upon the genes as comparable to enzymes, it becomes appropriate to inquire into the modern studies of enzyme molecules. (Northrop, 1937.) Pepsin and trypsin are reported to be "spherical" molecules very nearly the same size as ovalbumin, viz., with a molecular weight of about 34,000. The digestive enzymes for carbohydrates are credited with a molecule that falls apart into a distinctive, specific, possibly non-protein portion, bound chemically onto a non-specific portion which may differ even in the same enzyme, but which must have a colloidal character and is doubtless generally a protein. (Willstatter *et al.*, 1922; Waldschmidt-Leitz and Reichel, 1932.) The specific portion is represented as taking on molecules of the substrate, which thereby become susceptible of synthesis and hydrolysis. This two-parted structure has been postulated as a general characteristic of enzymes. Evidence for or against the generalization is scant, but there is at least one further example to be found in the "yellow oxidative enzyme", which is a union of a protein with "vitamin B_2", a specific active principle having a flavin structure. (Warburg and Christian, 1933; Euler and Adler, 1934.) The nucleus of the flavin residue is particularly well

shaped to superpose geometrically upon the hexagonal grid of a protein.



Thus from the analogy of enzymes we gather the suggestions that a complete gene molecule may have a molecular weight of comparable magnitude to what is prevalent among the water soluble proteins, and that involved in the molecule there may be a non-protein specific "prosthetic" group, or groups, very possibly having a condensed cyclic structure such as will superpose effectively upon the hexagons of the protein grid.

If the biological reduplication of genes, called for by cell division, is to be explained through chemical forces, it is requisite that the existing gene should have its parts so laid out in space that the new parts which must go into the newly constituted gene can be laid down upon the old as a direct pattern, each constituent close enough to its counterpart in the already existing gene to come within range of the chemical forces which must draw it into proper relative position, as if for crystal formation. (Gulick, 1937; Haldane, 1937.)

This requirement is not met satisfactorily by any hollow polyhedron, but is met admirably by the flat lattice configuration, with either one stratum, or a definite not too large number assembled in layer-cake form. The new lamellae needed during growth could then be accumulated either externally, by lateral accretion, or internally, by intussusception. Cleavage would occur by delamination, either just before or just after the additional lamellae had formed, provided, of course, that there must at the moment be an even number of lamellae, to allow of an equal and homologous cleavage through the mid-plane. It must needs be inferred that some particular small number of lamellae functions as a stable phase, which tends to be restored as soon as possible after each of the interruptions that are brought about by growth, cleavage, and conjugation.

We note that there are at least the following possibilities among lamellae-shaped molecules for the gene:

(1) the keratin or fibroid type of grid, including the Astbury and Lomax variant; (2) the cyclol grid; (3) a lattice built by the combination of protamine-like electro-positive fibers lying parallel in one direction bound together by salt formation with nucleic acid constituting electro-negative fibers running transversely to them; (4) and (5), respectively, fibrous or cyclol grids interlaminated with nucleic acid molecules to neutralize their diamino residues. It is probable that the third of these alternatives corresponds to the structure of the indifferent chromatin in the spermatozoa of the herring. Wrinch (1936a) has accordingly suggested that genes may consist of short segments—possibly short cylindrical shells—having this structure. As it appears to us that Wrinch's argument springs from too close an identification of genes with the transient protamine nucleate found in ripe spermatozoa of a few bony fishes, we hesitate to give precedence to this alternative over the others in the list, which latter conform to the structures of more complex proteins as worked out by Wrinch, by Astbury and Woods, and others.

It has more than once been proposed that the linear chain of genes can be explained in terms of bundles of parallel and similar protamine-like peptide molecules, perhaps each held together by nucleic acids, but maintaining their linear order by virtue of end-to-end salt-like linkages between the terminal carboxyls and amino groups of the peptides. For such a picture it is necessary to suppose that the identical peptides, built up in juxtapo-

sition, shall have all their carboxyls side by side at one end and all their free alpha-amino groups similarly at the other end. This compels an electrical polarity hardly compatible with the observation that segments of chromosomes in *Drosophila* and various plants may without harm be turned end-for-end within their respective chromosomes. (Kossikov and Muller, 1935.) The conclusion is almost forced upon us that the longitudinal binding must be by nucleic acid micels, whose opposite ends are both electro-negative, and that genes must be protein kernels of a type that can present electro-positive poles in both directions, namely either basic "globules" or lamellar proteins, or arrangements of protamine-like filaments lying transversely to the chromonema.

A suggestion by Caspersson (1936) is that the gene consists of a protein nucleate, the protein constituent being responsible for the diversity of genes, and the nucleic acid contributing to the non-specific internal mechanics of the genes. The zones of unconjugated protein (free from nucleic acid) found alternating with the chromatin nucleic acid in insect salivary cells he would not consider to be gene substance, although he does not claim that all nucleic acid is limited to genes. This viewpoint is in good agreement with Muller and Prokofyeva's interpretation of their observations on single-gene translocations.

The presumable parallelism between genes and viruses requires us to pay a little further attention to the data that we have cited for tobacco virus. If the Svedberg weight unit for the protein part of this material is 35,700, then each 2 Svedberg units (carrying 6 atoms of sulphur) are combined with 3 molecules of tetranucleotid. As the X-ray diffraction shows a strongly marked spacing of 15 mμ to 17 mμ, and none in the range of 3–4 mμ it appears that the fundamental particle size must be some higher multiple of the Svedberg unit. (Bawden and Pirie, 1937). There is also indication of a strong lamellar spacing at 1.1 mμ, but no lines in the neighborhood of .45 mμ and .35 mμ are outstanding enough to carry much significance (Wyckoff and Corey, 1936; Clark, 1938). A long list of further diffraction lines are shown, but no more detailed interpretation into three dimensions has been proposed thus far. The molecule evidently has a somewhat intricate lamellar pattern involving both the protein and the nucleic acid ingredients. By analogy it increases the likelihood that we shall eventually learn that genes are nucleoprotein molecules.

The process of gene mutation would appear in any of these pictures as a minor chemical alteration occurring at some spot in one lamella or in an attached prosthetic group. Delamination must then produce dissimilar genes, and if all the lamellae regenerate their own type, the two kinds of genes will soon both be established on a permanent basis.

Thus we find that the provisional sketch which chemistry can draught for a gene is not without its vivid tentative details. But we must keep scrupulously in mind that very nearly every item in the suggested space-relations still awaits confirmation or revision in the light of future experiment. We believe, not that science has solved these problems, but that it is now just coming within striking range of the question of the actual make-up of genes as chemical structures.

ARE GENES LIVING?

This humanly natural question stands somewhat in risk of becoming the starting point for mere quibbles over definitions. (Pirie, 1937; Bowden and Pirie, 1937). Life implies organization, and a gene has vastly less organization than a yeast, or

even a bacterium. The only practically significant approach to an answer is to consider whether genes are at a high enough level of organization and action so that there is value in applying to them the concepts that typify the biological sciences.

We have found that genes are able to reconstitute suitable nutrient material into identity with their own substance. They are capable of reproduction, in the sense that when a gene has generated material to the extent of reduplicating its mass, it is present as two complete and separate genes. They have a certain degree of instability, whereby they undergo alteration into new types that can thereafter perpetuate themselves. In short they unite the characteristics that render an organism capable of metabolism and amenable to natural selection and to the biological type of evolutionary processes. Consequently our first answer to the question, "are genes living?" is that in certain respects their status in research science requires us to handle them on the basis of characteristically biological concepts. To just that extent, then, it is scientifically good sense to consider them living. But this consideration places no prejudice against studying their chemistry in terms of chemical concepts, or against accepting evidence for a simpler constitution than is ordinarily looked upon as compatible with the adjective "living", and the practical validity of this statement must remain unimpaired even although the exact chemical configuration of representative genes should become known.

SUMMARY OF CONCLUSIONS, PARTS I AND II

In rehearsing the factual observations and the theoretical considerations respecting heredity, we find that any scientifically mechanistic account of the processes must be in terms of extremely minute physicochemical units whose characters are to be learned by inference, at least to a considerable extent. For some of the inferences we can claim an almost conclusive cogency; for some others the most that can be said is that they give valuable suggestions respecting an uncertain condition of affairs. Keeping in mind, then, that much of the subject still lies on the outer skirmish line of scientific exploration, nevertheless the following propositions seem to be justified:

(1) The actual material and structure of the genes is unknown, but the matrix in which or on which they are located and from which they must derive their substance, is a combination of nucleic acid with special proteins characterized by nitrogen-rich amino acids.

(2) It is uncertain as yet whether each gene consists of a single, huge molecule, or whether it may consist of a limited cluster of molecules. Certain lines of inference point toward a single molecule.

(3) The genes constitute but a small fraction of the mass of the chromosomes in which they are located. If we consider only the crucial differential substance, they cannot much exceed 3 per cent of the material content of salmon sperm heads. In *Drosophila*, different lines of evidence indicate a percentage of from not over 0.4 per cent up to perhaps 4.4 per cent.

(4) In the types of animals we have considered, the genes are ultramicroscopic, their size doubtless never exceeding 20 mμ in diameter, corresponding to a maximum volume of 4190 cu.mμ. It is unreasonable and superfluous, on the present evidence, to suppose that their principal dimensions fall below those of a molecule of ovalbumin, viz., to below linear dimensions of some 3.1 × 4.2 mμ. On a globular basis this gives a minimum volume of perhaps 38 cu.mμ., but if construed on a lamellar basis the minimum might be as

low as 9.5 cu.mμ. There are reasons for suspecting that these maximum and minimum bounds are well outside the actualities in the organisms that we have considered. The minimum volume is set by general considerations that apply wherever genes exist. The maximum is set by observations that might differ in other phyla of life (as for example the Liliaceae). This upper limit is not unthinkably small, as it exceeds the estimated minimum size of virus particles, and falls short of the highest estimates for the smaller viruses only to a reasonable degree.

(5) If the genes have a protein constitution (as is very probable), they may reasonably be pictured as having an internal lamellar structure, such as is shown by X-ray studies to be widespread among the proteins. During autosynthesis the hollow polyhedral form is hardly possible for genes, although it might be assumed at other times. Such lattice-shaped lamellar patterns as the hexagonal cyclol proposed for proteins by Wrinch (see figs. 3–7) or the rectilinear lattice described by Astbury and Woods, and by Clark and Shenk (Fig. 2), conform particularly well to the stipulations appropriate for a gene. An amino acid count lying between 70 and 80 to each lamella, corresponding to a protein molecular with 280 to 320 amino acids (or perhaps more specifically 288), is indicated for so long a list of native biological proteins, that one is impelled to bring up the possibility that the gene molecules and their lamellae carry the same numbers or perhaps some related characteristically stable number of amino acids. Their biologically reactive groupings may be incorporated in the lamellae, or may exist as attached prosthetic radicles.

(6) The chain of genes is carried in the chromonema, held in its alignment by chemical bonds arranged in a non-polar pattern. That is, either the gene molecules are basic proteins held in the chromonema by longitudinal nucleic acid molecules, or they are nucleoproteins some of whose nucleic acids straddle from gene to gene, or they are nucleoproteins alternating with a basic protein filling substance, to which they are bound on both sides by their nucleic acid valencies. In any case the chromonema structure depends at least in part upon acid bonds of nucleic acid, presented in both directions longitudinal to the chromonema, and is not to be explained by the hypothesis of longitudinal polypeptides that possess amino and carboxyl groups at their opposite ends.

(7) The total number of genes is moderately large, in *Drosophila* at least 2,000 for the haploid count, and possibly considerably more. No evidence now on hand calls for more than 5000, and they cannot be in excess of 13,000. There is some basis for the tentative surmise that the gene count in man may lie between 3.3 and 6 times that in *Drosophila*, viz. a haploid count between 6600 and 78,000.

(8) Among animals the genes of the haploid count are for the most part individually different from each other in a qualitative manner, and there is no wholesale duplication of comparable genes. A great part of their individual peculiarities and some, at least, of their mutations, are qualitative rather than quantitative.

(9) Genetic distinctions due to quantity differences (reduplication) are frequent and important in the higher plants. In animals quantity differences also exist, but seem to play a far less important rôle.

(10) Each gene has two types of action. The first is autocatalytic, whereby it conditions the formation of further molecules having the same peculiarities as its own. This power is highly specific, and yet flexible, in the sense that when altered by mutation the new gene perpetuates its new structure. It is also self-limiting in

the sense that the increase of mass is checked as soon as the mass is doubled and is not carried further till the chromosome has been divided. This specificity and self-limitation may well stand in some relationship to the probable laminated structure of their protein frame-work, or to some other unknown feature in their state of aggregation. It is possible that the pairing of like genes during maturation may be a further expression of the same insufficiently explained peculiarity that stabilizes their duplex condition. This chemical specificity is remarkably comparable to the specific selectivity of crystal formation.

(11) In addition to the autocatalytic effect they exert as their second activity an enzyme-like control over the formation of active substances that gives them a sort of long-distance control over cytoplasmic happenings. The active principles that they emit may well include hormone-like substances, but are doubtless in the main enzymes, possibly of the kinase type, or enzymes that generate other enzymes, perhaps some of them enzymes that generate hormones.

(12) As part of the evolutionary process, a gene must be credited with a liability for undergoing chemical alteration to produce a new gene substance with a slightly different molecular constitution, capable of autocatalysing itself, including the new item in its constitution. It would be theoretically conceivable that enzymes and hormones of the parent organism might sometimes induce heritable alterations in the structure of a gene, but experiments with transferred ovaries indicate that this does not actually occur. Most of the observed examples of heritable mutations reveal themselves as random losses or weakening of gene potency, but some cases of augmentation have also been verified. It has been found possible in a few instances to gather evidence that there is a qualitative aspect in the change of physiological effect, even where the effect produced is of a quantitative nature. These mutations occur in a sense at random, yet in accordance with the laws and limitations set up by the physico-chemical constitution of each mutating gene.

(13) Quantitative changes in the gene equipment also occur by "mutation." The best authenticated examples of these are numerical changes such as reduplication. Quantitative impoverishment of a gene could be supposed, theoretically, if the gene contains more than one molecule, but there is usually no way to differentiate between quantitative impoverishment and qualitative impairment of a catalytic agent; hence the great majority of mutations remain in an undistinguished class that may be either qualitative or quantitative.

(14) The two processes of gene reduplication and single-gene mutation, taken together, provide a possible mechanism by which a complex genetic machinery may be evolved out of simpler antecedents. Such a result might come to pass either through reduplication of genes followed by mutation alterations, or by a qualitative mutation followed by the intrusion of the altered gene into a chromosome beside the old gene.

(15) In the evolution of organisms, genes play a part, not merely by supplying the mutations among which natural selection must select, but furthermore by setting up barriers of mutual sterility, possibly through various kinds of translocations (producing semi-sterilities, etc.) or through serological mutations, or by releasing conditional lethals or making non-viable combinations. Only through the establishment of such physiological isolation is it possible for the path of evolution to bifurcate and produce radical

diversities. The extreme preciseness of the serial arrangement of genes in the normal germ cell finds much of its significance in its bearing on the mutual compatibilities and incompatibilities of biological strains. In other respects the space relations of the genes carried in a nucleus have at most only a small effect on heredity.

(16) Although small enough to be in the class of colloid micels, and probably not too complex to permit of the ultimate hope of learning much about their molecular constitution, we must still view the genes from the evolutionary standpoint as essentially living units, because they are subject to the biological type of evolutionary process. Very possibly they may be the smallest ultimate units that function according to biological categories.

(17) The ontological development whereby offspring come into the characteristics predetermined by their genic constitution is essentially a chapter in physiology. The evidence points in the direction that different organs in one organism are not customarily provided with very great (if any) differences in gene content, but rather that the differentiation comes about through a progressive physiological alteration of the cellular medium in which the genes are working, through accumulated chemodifferentiation, reciprocal hormonal effects, altered metabolic gradients, and the like. Thus every effect said to be produced by a gene is really brought about by reciprocal action of a gene with the rest of the cell, and in spite of the particularistic machinery the outcome always carries a totalitarian complexion.

LIST OF LITERATURE

Abderhalden, E. 1904. Die Monoaminosäuren des Salmins. *Ztsch. f. physiol. Chem.*, 41: 55–58.

——, and Rona, P. 1904. Die Abbauprodukte des "Thymushistons." *Ztsch. f. physiol. Chem.*, 41: 278–283.

Astbury, W. T., and Lomax, R. 1935. An X-ray study of the hydration and denaturation of proteins. *J. Chem. Soc.*, 1935, 846–851.

——, and Woods, H. J. 1933. X-ray studies of the structure of hair, wool, and related fibers. *Philos. Trans. Roy. Soc. London*, A 232: 333–394.

Bawden, F. C., and Pirie, N. W. 1937. The isolation and some properties of liquid crystalline substances, from solenaceous plants infected with three strains of tobacco mosaic virus. *Proc. Roy. Soc. London*, B 123: 274–320.

Bechold, H. 1934. Ferment oder Lebewesen? *Kolloid-Ztsch.*, 66: 329–340. 1934. Same title. *Kolloid-Ztsch.*, 67: 66–79.

Belling, J. 1931. Chromomeres of liliaceous plants. *Univ. of Calif. Pub. Bot.*, 16: 156–170.

Bells, A. K., and Lineweaver, Hans. 1937. Crystalline papain. *Science*, 86: 379.

Bergmann, Max, and Nieman, Carl. 1937. Newer biological aspects of protein chemistry. *Science*, 86: 187–190.

Bernal, J. D., and Crowfoot, Dorothy. 1934. X-ray photographs of crystalline pepsin. *Nature*, 133: 794–795.

Bridges, Calvin B. 1935. Salivary chromosome maps. *J. of Heredity*, 26: 60–64.

Burian, Richard. 1904. Chemie der Spermatozoen I. *Ergeb. d. Physiol.*, 3: 48–106.

——. 1906. Chemie der Spermatozoen II. *Ergeb. d. Physiol.*, 5: 768–846.

Burk, N. F., and Greenburg, D. M. 1930. The state of aggregation of certain proteins in urea-water solutions. *J. of Biol. Chem.*, 87: 197–238.

Calvery, H. O. 1932. Studies on crystallized egg albumin. *J. of Biol. Chem.*, 94: 613–634.

Caspersson, Torbjörn. 1936. Über den chemischen Aufbau der Strukturen des Zellkernes. *Skan. Arch. f. Physiol.*, 73: Suppl. No. 8 (151 pp.). See also 1937, same title. *Protoplasma*, 27: 463–467.

Castle, W. E. 1911. On "soma influence" in ovarian transplantation. *Science*, 34: 113–115.

——, and Phillips, John C. 1911. On germinal transplantation in vertebrates. *Carnegie Institution of Washington*, Pub. #144, 25 pp.

Clark, George L. 1938. Analysis by X-rays of ultimate structures of living materials. *Radiology*, 30: 180–190.

——, and Shenk, John H. 1937. X-ray diffraction studies of globular proteins. I. Egg albumin. *Radiology*, 28: 58–67.

Crowfoot, Dorothy. 1935. X-ray single crystal photographs of insulin. *Nature*, 135: 591–592.

DIETERLE, R. R. 1930. A modification of Macallum's hematozylin method for iron. *Arch. of Path.*, 10: 740–741.

DOBZHANSKY, TH. 1932. Cytological map of the X-chromosome of *Drosophila melanogaster*. *Biol. Ztrbl.*, 52: 493–509.

DOLLEY, D. H. 1909. The morphological changes in nerve cells resulting from over-work. *J. of Med. Research* 21: 95–113.

DUGGAR, B. M., and ARMSTRONG, J. K. 1923. Indications respecting the nature of the infective particles in the mosaic disease of tobacco. *Ann. Missouri Bot. Garden.*, 10: 191–112.

EKMAN, GUNNAR. 1930. Über Entwicklung und Vererbung eine theoretische Studie. *Annales Societatis Zoolog.-Bot Fennicae Vanamo*, 10: 1–140.

ERIKSSON-QUENSEL, I. B., and SVEDBERG, T. 1936. Sedimentation and electrophoresis of the tobacco-mosaic virus. *J. Am. Chem. Soc.*, 58: 1863–1867.

VON EULER, HANS. 1934. Neuere Ergebnisse an enzymatischen Oxidations- und Reduktions-Systemen. *Ergeb. d. Enzymforschung*, 3: 135–162.

——, and ADLER, ERICH. 1934. Über die Komponenten der Dehydrasesysteme. *Ztschr. f. physiol. Chem.*, 226: 195–212.

FEULGEN, R., and ROSSENBECK, H. 1924. Mikroskopisch-chemischer Nachweis einer Nucleinsäure. *Ztsch. f. physiol. Chem.*, 135: 203–248.

GILSON, G. 1892. On the affinity of nuclein for iron and other substances. *Rep. of Brit. Ass. for Adv. of Sci.*, 1892: 778–780.

GOLDSCHMIDT, RICHARD. 1927. Physiologische Theorie der Vererbung. J. Springer, *Berlin*, 247 pp.

——. 1928. The gene. QUART. REV. OF BIOL., 3: 307–324.

GOWEN, J. W., and GAY, E. H. 1933. Gene number, kind and size in *Drosophila*. *Genetics*, 18: 1–31.

——, and PRICE, W. C. 1936. Inactivation of tobacco-mosaic virus by X-rays. *Science*, 84: 536–537.

GULICK, ADDISON. 1937. Some contributions of chemistry to the theory of the gene. *Proc. Mo. Acad. Sci.*, (Apr., '37) 3: 75–77.

HALDANE, J. B. S. 1937. The biochemistry of the individual. In Perspectives in Biochemistry (Needham and Green, Editors), p. 1–10.

HEAPE, WALTER. 1890. Preliminary note on the transplantation and growth of mammalian ova within a uterine foster-mother. *Proc. Roy. Soc. London*, 48: 457–458.

——. 1897. Further note on the transplantation and growth of mammalian ova within a uterine foster-mother. *Proc. Roy. Soc. London*, 62: 178–183.

HODGE, C. F. 1892. A microscopical study of changes due to functional activity in nerve cells. *J. of Morphol.*, 7: 95–168.

JORDAN-LLOYD, D. 1932. Colloidal structure and its biological significance. *Biol. Rev.*, 7: 254–273.

——. 1937. Recent developments in our knowledge of the protein molecule. In Perspectives in Biochemistry (Needham and Green, Editors), p. 23–35.

JORPES, ERIK. 1934. Pentose polynucleotid of pancreas. *Biochem. J.*, 28: 2102–8.

KIESEL, A., and BELOZERSKI, A. 1934. Über die Nucleinsäure und die Nucleoproteide der Erbsenkeime. *Ztsch. f. physiol. Chem.*, 229: 160–166.

KLEIN, V., and ROSSI, A. 1935. Experimentelle Studien über den Nukleinstoffwechsel, XXXVI. Fermentative Untersuchungen über den Aufbau des Polynucleotids. *Ztsch. f. physiol. Chem.*, 231: 104–114.

KOLTZOFF, N. K. 1928. Physikalisch-chemische Grundlage der Morphologie. *Biol. Ztrbl.*, 48: 345–374.

KOSSEL, A. 1903. Zur Kenntnis des Salmins. *Ztsch. f. physiol. Chem.*, 40: 311–315.

——. 1928. The Protamines and Histones. Longmans Green, *London* and *New York*, 107 pp.

——, and KUTSCHER, F. 1900. Beiträge zur Kenntnis der Eiweisskörper. *Ztsch. f. physiol. Chem.*, 31: 165–214.

KOSSIKOV, R. V., and MULLER, H. J. 1935. Invalidation of the genetic evidence for branched chromosomes. *J. of Heredity*, 26: 305–317.

KRUEGER, A. P. 1936. The nature of bacteriophage and its mode of action. *Physiol. Reviews*, 16: 129–172.

LEIPERT, TH., and KUROKAWA, T. 1933. Zur Chemie der Vogelblutkerne. *Biochem. Ztsch.* 261: 425–432.

LEMAR, JOHN D., and MYERS, JOHN T. 1935a Studies on the nature of bacteriophage I. Extraction of Bacteriophage by ether. *J. of Inf. Dis.*, 57: 1–5.

——. 1935b. Studies on the nature of Bacteriophage II. Artificial production of a specific lytic agent. *J. of Inf. Dis.*, 57: 6–11.

LEVENE, P. A. 1921. On the structure of thymus nucleic acid. *J. of Biol. Chem.*, 48: 119–125.

——, and BASS, L. W. 1931. Nucleic acids. Chemical Catalog Co., *New York*, 327 pp.

——, MIKESKA, L. A., and MORI, T. 1930. On the carbohydrate of thymonucleic acid. *J. of Biol. Chem.*, 85: 785–787.

LINDERSTRØM-LANG, K. 1935. Some electrochemical properties of a simple protein. *Trans. Faraday Soc.*, 31: 324–335.

LORING, H. S. 1938. Nucleic acid from tobacco mosaic virus protein. *Proc. Am. Soc. Biol. Chem.*, 1938. (In press, in *Jour. of Biol. Chem.*)

MACALLUM, A. B. 1895. On the distribution of assimilated iron compounds, other than hemoglobin and hematins, in animal and vegetable cells. *Quart. J. of Micr. Soc.*, 38: 175–274.

——. 1897. On a new method of distinguishing between organic and inorganic compounds of iron. *J. of Physiol.*, 22: 92–98.

——. 1908. Die methoden und Ergebnisse der Microchemie in der biologischen Forschung. II. Das Eisen in Geweben und Zellen. *Ergeb. d. Physiol.*, 7: 565–600.

——. 1926. The paleochemistry of the body fluids and tissues. *Physiol. Reviews*, 6: 316–357 (cf. pp. 348–350).

MACKENSEN, OTTO. 1935. Locating genes on salivary chromosomes. *J. of Heredity*, 26: 163–174.

MCKINNEY, H. H. 1937. Virus mutation and the gene concept. *J. of Heredity*, 28: 51–57.

MARCUS, H. 1921. Über die Struktur des menschlichen Spermiums. *Arch. f. Zellforschung*, 15: 445–448.

MARRACK, JOHN, and HEWETT, L. F. 1929. The osmotic pressure of crystalline egg albumin. *Biochem. J.*, 23: 1079–1080.

MATHEWS, A. P. 1897. Zur Chemie der Spermatozoen. *Ztsch. f. physiol. Chem.*, 23: 399–411.

METZ, C. W. 1935. Structure of the salivary gland chromosomes in *Sciara*. *J. of Heredity*, 26: 177–188.

——. 1935. Internal structure of salivary gland chromosomes in *Sciara*. *J. of Heredity*, 26: 491–501 (Dec. '35).

MIESCHER, F. 1874a. Die Spermatozoen einiger Wirbelthiere. *Verh. d. naturf. Ges. in Basel*, 6: 138–208.

——. 1874b. Das Protamin, eine neue organische Basis aus den Samenfäden des Rheinlachses. *Ber. d. deutsch. chem. Ges.*, 7 (I): 376–379.

——. 1897. Die histochemischen und physiologischen Arbeiten. F. C. W. Vogel, *Leipzig*, 543 pp.

——, and SCHMIEDEBERG, O. 1896. Physiologisch-chemische Untersuchungen über die Lachsmilch. *Arch. f. exp. Path. u. Pharm.*, 37: 100–155.

MORGAN, T. H. 1922. On the mechanism of heredity. *Proc. Roy. Soc. London*, B 94: 162–197.

——. 1928. The Theory of the Gene. 2nd Ed. Yale Univ. Press, 358 pp.

MÜHLMANN, M. 1928. Hämatoxylin als Reagens auf Eisen. *Arch. f. pathol. Anat.*, 266: 697–711.

MULLER, H. J. 1922. Variation due to change in the individual gene. *Amer. Nat.*, 56: 32–50.

MULLER, H. J. 1929. The gene as the basis of life. *Proc. Internat. Congr. of Plant Sci.*, 1: 897–921.

——. 1935. On the dimensions of chromosomes and genes in dipteran salivary glands. *Amer. Nat.*, 69: 405–416.

——, and ALTENBERG, E. 1919. The rate of change of hereditary factors in *Drosophila*. *Proc. Soc. Exp. Biol. and Med.*, 17: 10–14.

——, and PAINTER, T. S. 1932. The differentiation of the sex chromosome of *Drosophila* into genetically active and inert regions. *Ztsch. f. indukt Abstamm. u. Vererbl.*, 62: 316–365.

——, and PROKOFYEVA, H. A. 1934. Continuity and discontinuity of the hereditary material. *C. R. d. Acad. Sc. d. U. S. S. R.*, 4: 74–83.

——, ——. 1935. The individual gene in relation to the chromomere and the chromosome. *Proc. Nat. Acad. Sci.*, 21: 16–26.

NEUMANN, A. 1898. Zur Kenntnis der Nukleinsubstanzen. *Arch. f. Anat. u. Physiol.* (*Physiol. Abt.*) 1898: 374–378.

NICHOLS, J. B. 1930. Molecular weight of egg albumin II. In the presence of electrolytes. *J. Amer. Chem. Soc.*, 52: 5176–5187.

NORTHROP, J. H. 1937. The formation of enzymes. *Physiol. Rev.*, 17: 144–152.

DU NOÜY, P. L. 1925. The probable dimensions of the molecule and molecular weight of crystalline egg albumin. *J. of Biol. Chem.*, 64: 595–613.

PAINTER, T. S. 1931. A cytological map of the X-chromosome of *Drosophila melanogaster*. *Science*, 73: 647–648.

——. 1934. Salivary chromosomes and the attack on the gene. *J. of Heredity*, 25: 465–476.

PATTERSON, J. T. 1932. Lethal mutations and deficiencies produced in the X-chromosome of *Drosophila melanogaster* by X-radiation. *Amer. Nat.*, 66: 193–206.

PHILPOT, J. ST. L., and ERIKSSON, J. B. 1933. Ultracentrifugal study of crystalline pepsin. *Nature*, 132: 932–933.

PICCARD, J. 1874. Über Protamin, Guanin, und Sarkin als Bestandteile des Lachssperma. *Ber. d. deutsch chem. Ges.*, 7: 1714–1719.

PIRIE, N. W. 1937. Meaninglessness of the terms life and living. In "Perspectives in Biochemistry." (Needham & Green, Editors) p. 11–22.

POLICARD, A. 1933. Les matières minérales fixes des éléments séminaux au cours de la spermatogénèse. *Bull. d'histol. appliq. à la physiol.*, 10: 313–320.

——. 1934. Sur l'existence de fer dans le noyau cellulaire. *Bull. d'histol. appliq. à la physiol.*, 11: 216–219.

POLICARD, A., and ROJAS, P. 1935. Estudio por microincineracion de los globulos rojos en *Cichlasoma fascetum* (Teleoteos). *Rec. Soc. Argent. de. Biol.*, 11: 164. (By abstract, *Physiol. Abstracts*, 20: 553.)

RAINEY, R. C. 1937. Absolute configuration of the naturally occurring α amino-acids. *Nature*, 140: 150.

RENNER, O. 1934. Die pflanzlichen Plastiden als selbstständige Elemente der genetischen Konstitution. *Ber. d. math. phys. Klasse d. sächsischen Akad. d. Wiss., Leipzig*, 86: 241–266.

RIECKER, HERMAN H. 1929. Relation of chromatin to hemoglobin and bilirubin. *J. of Exp. Med.*, 49: 937–943.

SCHMIEDEBERG, O. 1900. Über die Nukleinsäure aus der Lachsmilch. *Arch. f. exp. Path. u. Pharm.*, 43: 57–83.

SCOTT-MONCRIEFF, ROSE. 1937. The biochemistry of flower color variation. In Perspectives in Biochemistry (Needham and Green, Editors), p. 230–243.

STADLER, L. J. 1932. On the genetic nature of induced mutations in plants. *Proc. Sixth Internat. Congr. Genetics, Ithaca, N. Y.*, I: 274–294.

STANLEY, W. M. 1935a. Isolation of a crystalline protein possessing the properties of tobacco-mosaic virus. *Science*, 81: 644–5.

——. 1935b. Isolation of a crystalline protein possessing the properties of tobacco-mosaic virus. IV. Effects of different chemical agents on infectivity. *Phytopathol.*, 25: 899–921.

——. 1937a. Report at meetings of A. A. A. S., Princeton, Dec. 1936. See *Science News Letter*, Jan. 9, 1937, p. 20.

——. 1937b. Some biochemical investigations on the crystalline tobacco-mosaic virus proteins. *Proc. Am. Philos. Soc.*, 77: 447–453.

SVEDBERG, T. 1931. Molecular weights of proteins in their native state. *Nature*, 128: 999–1000.

——, and NICHOLS, J. B. 1926. Molecular weight of egg albumin (1) Electrolyte-free condition. *J. Am. Chem. Soc.*, 48: 3081–3092.

TAKAHASHI, H. 1932. Enzymic dephosphoration of nucleic acid. *J. of Biochem., Japan*, 16: 463–81.

TAKAHATA, Y. 1924. Über den Eisengehalt der Nucleoproteide. *Ztsch. f. physiol. Chem.*, 136: 214–218.

THANNHAUSER, S. J. 1934. Stoffwechselprobleme (Vorträge). J. Springer (*Berlin*) 101 pp.

THORNBERRY, H. H. 1935a. Quantitative studies on the filtration of tobacco-mosaic virus. *Phytopathol.*, 25: 601–617.

——. 1935b. Particle diameter of certain plant viruses. *Phytopathol.*, 25: 938–945 (Oct. '35).

TROLAND, L. T. 1917. Biological enigmas and the theory of enzyme actions. *Amer. Nat.*, 51: 321–350.

WALDSCHMIDT-LEITZ, E., and REICHEL, M. 1932. Zur Frage der chemischen Natur der Pankreasamylase. *Ztsch. f. physiol. Chem.*, 204: 197–203.

WAUGH, J. G., and VINSON, C. G. 1932. Particle size of the virus of tabacco-mosaic in purified solutions. *Phytopathol.*, 22: 29.

WARBURG, OTTO, and CHRISTIAN, WALTER. 1933. Über das gelbe Ferment und seine Wirkung. *Biochem. Ztsch.*, 266: 377–411.

WILLSTÄTTER, R., GRASER, J., and KUHN, R. 1922. Zur Kenntnis des Invertins. *Ztsch. f. physiol. Chem.*, 123: 1–78.

VAN WISSELINGH, C. 1920. Über Variabilität und Erblichkeit. *Ztsch. f. ind. Abst. u. Vererbl*, 22: 65–126.

WRINCH, D. M. 1934. Chromosome behavior in terms of protein pattern. *Nature*, 134: 978.

——. 1936a. On the molecular structure of chromosomes. *Protoplasma*, 25: 550–569.

——. 1936b. Structure of proteins and of certain physiologically active compounds. *Nature*, 138: 651–652.

——. 1937a. On the pattern of proteins. *Proc. Roy. Soc. London*, A 160: 59–86.

——. 1937b. On the structure of insulin. *Science*, 85: 566–567.

——. 1937c. The cyclol theory and the "globular" proteins. *Nature*, 139: 972–973.

——, and JORDAN, LLOYD D. 1936. The hydrogen bond and the structure of proteins. *Nature*, 138: 758–759.

WYCKOFF, R. W. G., and COREY, R. B. 1936. X-ray diffraction patterns of crystalline tobacco-mosaic proteins. *J. of Biol. Chem.*, 116: 51–56.

WYCKOFF, R. W. G., and EBELING, A. H. 1933. Some ultraviolet photomicrographs made with different wave lengths. *J. of Morphol.*, 55: 131–136.

——, ——, and TER LOUW, A. L. 1932. A comparison between the ultraviolet microscopy and the Feulgen staining of certain cells. *J. of Morphol.*, 53: 189–200.

YAMAGAWA, M., and NISHIZAWA, T. 1934. Chemical study of protamines, VI. Acid hydrolysis of salmine. *J. Imp. Fisheries Inst., Japan*, 30: 97–115.

SECRETIONS FROM ECTODERMAL GLANDS OF ARTHROPODS

By N. S. R. MALOEUF

Sterling Fellow, Yale University; Contribution from the Osborn Zoological Laboratory, Yale University

THE products of secretion of the different types of hypodermal glands differ greatly and show that cells of a common embryonic external layer (the ectoderm) eventually come to produce substances of, often, entirely unrelated composition. The cuticle in general and the cuticular pigments are hypodermal secretions which, however, will not be treated here. There are many secretions of hypodermal origin, the physiological or chemical properties of which have never been studied and which cannot therefore be included in this review.

A. PRODUCTS OF THE "TEGUMENTAL" GLANDS

When, prior to the molting of a decapod crustacean (Yonge, '32), the newly forming cuticle beneath the old cuticle is about 2 microns thick there is, here and there, a secretion apparent at the outer surface of the new cuticle at openings of the ducts of the tegumental glands (Fig. 1, *t*). The new epicuticula is not as yet formed. After each molt these glands degenerate and eventually disappear. New glands develop between molts and display the greatest secretory activity at the time when the epicuticle, *ep*, is being most rapidly formed. There are very distinct differences in physico-chemical constitution between the epicuticle and the rest of the cuticle. Yonge further showed that the properties of the epicuticle are the same as those of the fluid contained in the ducts, *dt*, of the tegumental glands. Thus, both the epicuticle and the fluid in the ducts have a special affinity for basic stains (therefore, have an acid reaction), an isoelectric point at pH 5.1, are resistant to concentrated mineral acids, are not attacked by chitinase, and yield a positive test for lipoids. The conclusion that the epicuticle of decapod Crustacea is the product of the tegumental glands appears evident.

The secretion of these glands, apparently a lipoid material, must possess a low surface tension to be capable of spreading as a thin sheet over the surface of the cuticle. During the process of its formation the new epicuticle is protected by the old cuticle. By virtue of its very low surface tension, the secretion of the tegumental glands surrounds the otoliths of the statocysts and thus connects them, by thin strands, to the setae (Prentiss, '01; Lang and Yonge, '35; Yonge, '35a). In the same manner, the eggs are attached to the pleopods of the female (Yonge, '35b, '37, '37a). "The intimate association between ovulation and secretion by the oviduct and the cement (tegumental) glands points, in the apparent absence of nerve connections to the cement glands and also in the oviducal epithelium, to the presence of some controlling hormone."

Such glands in decapods have been

described anatomically by Vitzou (1882), Herrick (1895), and, according to Yonge, by Braun and Farkas. They occur over the entire surface of the body in all decapods studied.

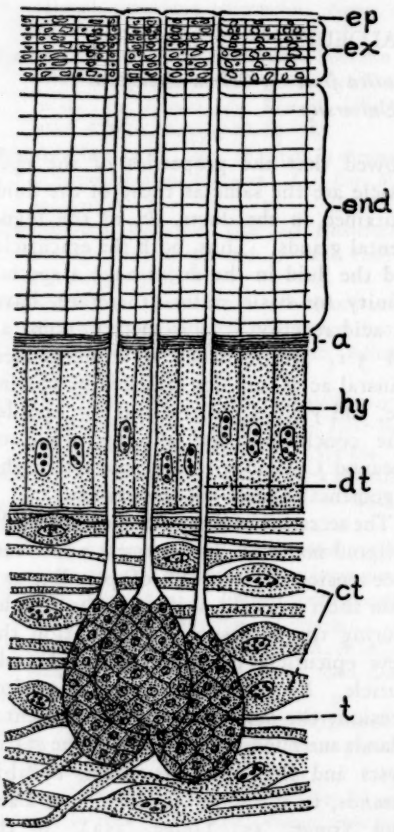


FIG. 1. GENERALISED TRANSVERSE SECTION THROUGH THE FULLY FORMED INTEGUMENT OF A DECAPOD

a, accessory cuticular layer; *ct*, conjunctival tissue; *dt*, duct of tegumental gland; *end*, endocuticula; *hy*, hypodermis; *t*, tegumental gland. (Adapted from Vitzou; Verne; and Yonge.)

In insects, on the other hand, the epicuticle is the first layer of the cuticle to be formed and is secreted by the whole outer surface of the hypodermal cells (Wigglesworth, '33).

It may be that the epicuticle of arthropods protects the newly forming cuticle beneath from the digestive action of the exuvial glands. The latter secrete a fluid which digests a considerable amount of the organic material of the old cuticle (see below).

B. MUCOUS GLANDS

Certain glands in the gills of brachyuran and macruran Crustacea (Cuénot, 1895) secrete a mucous-like substance which gives the typical colors of mucous with various basic dyes. In some cases, when a crayfish (*Cambarus bartoni*) is allowed to reduce the oxygen concentration of the external medium it secretes a protein, probably a glucoprotein such as mucous, when the oxygen concentration falls to a low level. This protein acts as a buffer by combining with some of the excess carbon dioxide in the medium (Maloeuf, '36).

It is not surprising to know that modified hypodermal cells secrete mucous, for, the hypodermal cells secrete chitin, which, like mucous, yield a monosaccharid-amine upon hydrolysis. This amine is glucosamine in chitin, and galactoseamine in mucous.

The secretion of mucous by glands in the gills of certain Crustacea results in a coating of the gills when the animals are out of the water and thus prevents dessication through the gill filaments and, also, probably aids in gaseous exchange by moistening the cuticular surface of the gill filaments.

In the crustacean *Chirocephalus diaphanus* (Cannon, '28 and '35) the food particles are arrested in the maxillary region by the entangling secretion of the labral glands, and the mass is pushed into the mouth by the maxillules.

C. LIPIDS

1. Oil. Oils and fats are fatty acid esters of the triatomic alcohol glycerin. "Oil" here is synonymous with a liquid fat and is, thus, non-volatile. Unicellular glands, which probably secrete the oil which renders the spiracular tubes of mosquito larvae hydrofugous, have been observed by Keilin, Tate, and Vincent ('35) and their predecessors.

2. Fat. The "woolly louse," *Schizoneura lanigera* (Aphididae), is so called because of the presence on its cuticle of "waxy" or "wooly" fibers. These are the products of numerous hypodermal glands. Schulz ('22) has shown that these fibers are not wax at all, as they grossly appear to be, but are a glycerid of a saturated fatty acid or of saturated fatty acids and are, therefore, fat. The kind (or kinds) of fatty acid entering into the constitution of the fat has (or have) not as yet been determined.

Fat-secreting glands occur at the posterior end of the abdomen of bees and wasps. They lubricate the sting stylets (Heselhaus, '22).

3. "Wax." "Waxes" are generally mixtures of fatty acid esters of mono- or dihydroxy saturated alcohols and paraffins. At one extreme, cocksfoot wax consists almost entirely of primary alcohol while, at the other extreme, tobacco leaf wax is made up exclusively of paraffins. "Wax, in a broad technical sense, is a hard, high-melting material containing no glycerides, and not in the strict chemical sense of a long chain ester" (Chibnall and Piper, '34).

Wax is secreted by the aphid "wooly louse" *Pemphigus xylostei* (Schulz and Becker, '31) during all stages subsequent to the first larval instar, by the beetles *Lindorus lophanthae* and *Rhizobius ventralis* (Flanders, '30), and by bees. Wax glands are unicellular and the cuticle bounding such is very thin. Rogojanu ('34) could find no pores in the coccid, *Eriosoma*, and thus concluded that the wax makes its exit in a liquid state. In the case of the coccid, *Orthezia*, he observed wax to be discharged at the apex of a hollow hair by a rupture of the tip. In the case of the honeybee, Dreyling ('03) stated that in order to observe pores to the exterior it is necessary to make very thin sections and observe through highest magnifications. Wax pores lined with cuticle have also been described in dragonflies (Schulze, '34) and coccids (Pollister, '37).

Until the end of the eighteenth century it was commonly supposed that the wax of bees is manufactured directly out of pollen ("farina"). That wax and pollen are two distinctly different substances was shown to be so by Hunter (1792) who arrayed the following crude yet substantial facts in support of his demonstration:

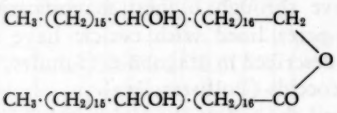
1. Pollen burns, but in so doing does not smell like wax. 2. Pollen is of different colors on different honeybees, whereas newly made comb is all of the same color. 3. Pollen is gathered with greater avidity for old hives in which the wax combs are complete. 4. In the first formation of the combs of a hive the bees seldom bring in any pollen. Pollen is later brought in for the hatched larvae. 5. As much comb is formed when the swarm is in the hive, i.e. during cold or wet weather, and when the bee thus cannot secure pollen. 6. Wax is *secreted* externally between the scales of the underside of the abdomen. 7. "I took several scales on the point of the needle and held them to a candle, whereas they melted, and immediately formed themselves into a round globe." 8. These scales are found only during the time when wax combs are being constructed.

Hunter's observations are convincing even though they do not quite attain up-to-date analytical requirements. While the wax of bees is the product of the synthetic activity of the modified hypodermal cells of the abdominal sterna, the raw materials out of which wax is

synthesized come from the honey ingested —a carbohydrate food, and not from pollen—mainly a protein food. Chibnall and Piper ('34) have suggested a probable scheme for the metabolic formation of waxes from sugars.

A study of the chemical constitution of the wax secreted by *Pemphigus* was made by Schulz and Becker ('31).

They ascribed the following structural formula to this wax:



or the empirical formula, $C_{68}H_{136}O_4$. It was considered that this wax could be split up into the diatomic alcohol, "pemphigus alcohol" [$C_{34}H_{68}(OH)_2$] and the fatty acid, "pemphigus acid" ($C_{33}H_{67}$-OH·COOH). This wax, they stated, is not identical with that secreted by the psyllid bug, *Psylla alni*, but is closely similar to that of the bettle *Coccinella*.

The important work of Chibnall and his school (Chibnall, Latner, Williams, and Ayre, '34; Piper, Chibnall, and Williams, '34; Chibnall, Piper, Pollard, Williams, and Sahai, '34; Chibnall and Piper, '34; Pollard, Chibnall, and Piper, '31; Francis, Piper, and Malkin, '30) with the use of X-ray analysis, has shown, however, "that all the names which have been assigned by previous workers to primary alcohols, fatty acids and paraffins isolated from waxes have been given to products that are not chemical entities but mixtures." Among others, this refers to Liebermann's (1885, 1887) work on the wax of *Coccus cacti*, Gascard and Damoy's ('23, '23a) studies on bees' wax, Sundwick's ('01) work on *Psylla* wax and the paper of Schulz and Becker (*loc. cit.*). Chibnall *et al.* showed that cochineal wax from *Coccus cacti* is relatively simple, consisting of 15-keto-*n*-tetratriacontanol (cocceryl alcohol), *n*-triacontanoic acid, and 13-keto-*n*-dotriacontanoic acid. Bees' wax was much more complex containing all the even-number primary alcohols from C_{24}–C_{34} inclusive and probably all the even-number *n*-fatty acids from C_{24}–C_{34} in addition to four paraffins. Chibnall *et al.* showed that all the primary alcohols and *n*-fatty acids present in waxes contain an even number of carbon atoms and that all waxes are essentially of the same general type; have even-number primary alcohols and *n*-fatty acids from C_{24}–C_{36} and odd-number paraffins from C_{25}–C_{37}.

The yellowish color of wax secreted by honeybee workers is due to the presence of a flavone derivative, possibly 1.3-dioxyflavone (Jaubert, '27).

The behavior of bees when in the process of wax and comb manufacture is very interesting and has been described by Comstock (1895).

"When a colony needs wax", wrote Comstock, "many of the workers gorge themselves with honey, and then hang quietly in a curtain-like mass . . . After about twenty-four hours there appears on the lower surface of the abdomen of each bee little plates of wax that are forced out from openings between the ventral abdominal segments called wax-pockets. Other workers attend to this curtain and collect the wax as fast as it appears, and use it at once in constructing combs. As it requires about twenty-one pounds of honey to make one pound of wax, the bees, who are true economists, make this expensive product go as far as possible. The hexagonal cells of the honeycomb afford an ideally compact arrangement, as if the bees were mathematicians and had fully planned to secure the most room in the least space. The cells of the comb are used both for rearing the young and for storing food. . . . Honey is regurgitated into the cells of the comb."

The honey stored by the bee is digested nectar which is transported to the hive and stored as an easily assimilable source of carbohydrate for the synthesis of wax. Thus, by supplying the bee hive with artificial combs, the bee-keeper makes it possible to breed bees for profit by selling stored honey.

In part because of the use of wax in churches, bees have been upheld as sacred animals. "The wax of bees," wrote de Gubernatis (1872), "because it produces light, and is, moreover, used in churches, must have had its part in increasing the divine prestige of bees." The "virgin birth" (parthenogenetic development) of the drones has also contributed to the sanctity of bees. Thus Aristoteles wrote that the hornets and wasps "have nothing divine about them as the bees have. For the so-called 'mothers' generate the young . . . but they generate by copulation with one another, for their union has often been observed." Parthenogenesis, nevertheless, occurs in wasps too.

D. PRODUCTS OF THE EXUVIAL GLANDS

1. Occurrence and structure of the glands. Exuvial (molting, or Versonian) glands, were probably first definitely observed by Verson (1890) in silkworm larvae, in each of which there are fifteen pairs of such glands. Each one of these glands, in the silkworm, is a very much enlarged and vacuolated hypodermal cell communicating with the outer surface of the old cuticle by a relatively wide and short duct (Verson, 1890; Wachter, '30). In the larvae of the bug, *Rhodnius* (Wigglesworth, '33), each gland is formed of three hypodermal cells and communicates with the exterior by means of a fine duct which is apparently lined with cuticle and extends into the interior of the gland. The glands are absent from the adult bugs.

The cells, or cell, of these glands enlarge and become vacuolated prior to the period of molting (ecdysis). Tower ('06) observed that after ecdysis and especially after pupation the exuvial glands of coleopterous larvae degenerate rapidly. The studies of Hoop ('33) on the exuvial glands have shown that, in the dipterous larva, *Limnophila fuscipennis*, very large cells lie in the haemocoele against the much smaller hypodermal cells. Only the last larval molt was investigated in this case, i.e. that prior to the formation of the pupa. Very shortly before the molt the cells enlarge and become vacuolated. After the molt they shrink and lose their vacuoles. The same applies to the hymenopterous larva, *Nematus*. These large monocellular glands, unlike the exuvial glands of *Rhodnius*, do not degenerate even after the final molt.

Other somewhat smaller cells which contain large globules just before a molt but which degenerate after the last larval molt (this being the only molt investigated) were observed in the hypodermis of *Limnophila*.

In no case did Hoop find a duct leading to the outer surface of the cuticle in any insect studied. No special exuvial cells could be found in larvae of the blowfly, *Calliphora*, or in the tracheae or fore and hind guts of any species. It should be noted, nevertheless, that the presence of molting fluid between the old and new cuticles in all the above cases as well as in between the old and new tracheal cuticles, indicates that some sort of fluid-secreting (exuvial) glands are present in all cases. Hoop, therefore, suggested that, in *Calliphora*, the hypodermal cells as a whole secrete the exuvial or molting fluid.

It may be significant to note that Wigglesworth found that the oenocytes (relatively large ectodermal cells confined to the hypodermis in *Rhodnius*) enlarge prior to a molt and later become reduced in size. They are, however, probably not directly concerned with the secretion of the exuvial fluid since they are quite ductless and persist in the adult. Suggestions as to the functions of the oenocytes are offered below.

Exuvial glands, so far as I know, have not as yet been described in other arthro-

pods. They probably will be found, however, if looked for.

2. *Function.* It is a generally observed fact that, at the time when the old cuticle is cast off, insects are almost dry. Shortly prior to the act of molting the silkworm (Wachter, '30) swallows its molting fluid. This is followed by a wrinkling of the old cuticle. In the bug, *Rhodnius* (Wigglesworth), the molting fluid is not swallowed but is reabsorbed through the new cuticle. It is therefore quite evident, as Wigglesworth pointed out, that, *whatever the function of the molting fluid, that function is exerted before the act of molting*, for, the molting fluid is then abundant between the old and new cuticles.

What then is the function of the molting fluid? Wigglesworth has found that fully 86.5 per cent of the old abdominal cuticle of *Rhodnius* is reabsorbed before molting. The decrease in depth of the old cuticle as time for ecdysis draws near is very marked. The marked loss in mass of the shed cuticle has been observed in insects and other arthropods and has been quantitatively studied by Herrick (1895), Drach ('35 a, b), and Robertson ('37) in decapod Crustacea. Since the cuticle contains protein and chitin, Wigglesworth concluded that the exuvial fluid must contain a proteinase and a chitinase. The presence or absence of enzymes was not, however, determined; nor were the absolute amounts of chitin in the exuvium (cast-off cuticle) and in the old cuticle, before its shedding, analyzed. While, therefore, it seems probable that the chitin of the old cuticle is partly digested and absorbed, we are not sure that this is the case. Chitinase has not as yet been definitely found in arthropods and the discovery of its production by the exuvial glands would be of interest.

"There is no doubt, I believe, that you would find less chitin in the exuvium than in the fully developed cuticle. It seems to me that there must be a chitinase in the molting fluid to break down the endocuticula of the old cuticle and to build it up into the new" (Campbell, personal communication).

In view of the fact that enzymes possess protein properties and that proteins cannot diffuse through cell membranes, the discovery of Hoop and Wigglesworth that the exuvial glands disintegrate after each molt acquires meaning. The cell membrane must rupture at some point to liberate the enzymes. It should be mentioned, however, that Hoop did not recognize the significance of this for he wrote that "these latter are considered molting glands by some but surely cannot be so owing to their subsequent degeneration."

By the method of injections into various moth larvae, Schürfeld ('35) has indicated that the exuvial glands are concerned solely with the liberation of the exuvial fluid and do not secrete a molting or a metamorphosing hormone.

E. PRODUCTS OF THE LABIAL GLANDS

These glands arise in the embryo as paired ectodermal invaginations of the ventral region of the second maxillary (labial) sternum of insects. They are often known as "salivary glands." As will become apparent below, they do not in all cases contain digestive enzymes, as do the salivary glands of vertebrates, and often serve other functions, such as preventing the coagulation of the blood of vertebrates. In this category also belong the silk glands of hymenopterous and lepidopterous larvae. In arachnids, "myriapods," and *Peripatus*, what are possibly homologues of these glands open into the anterior end of the fore gut. There is as yet no satisfactory evidence for the presence of such glands in the Crustacea.

1. "Saliva"

(*a*) *Hydrolyzing enzymes.* The macerated salivary glands of the scorpion (Sarin, '22), a carnivorous animal, contain no catalase, amylase, inulase, and no sucrase. They do contain the proteolytic enzymes, pepsinase and trypsinase. Lipase and chymosinase (a milk coagulant) were noted in one out of the three cases studied. The secretion of proteolytic enzymes from the salivary glands of scorpions and spiders is typical of the condition among arachnids since all living arachnids except *Limulus* (Yonge, '37) have adopted a suctorial habit which may be partly responsible for the retention of some degree of intracellular digestion in these animals.

The salivary glands of honeybee larvae do not secrete an amylase even though the blood contains this enzyme (Bertholf, '27). Accordingly, these larvae were found incapable of utilizing starch or glycogen. The demonstration of the secretion of sucrase and amylase by the salivary glands of honeybee worker adults, on the other hand, appears conclusive. Pavlovsky and Zarin ('22) offered a thick aqueous, enzyme-free solution of sucrose to honeybee adult workers. The honey which the bees subsequently regurgitated contained sucrase and amylase. They do not consider that these enzymes could have been introduced into the "honey stomach," or crop, from the mid gut for two reasons. Firstly, the valves between the "honey stomach" and the mid gut would probably prevent an exgurgitation of the mid gut contents; and, secondly, catalase, which is invariably present in the mid gut, would appear in the "honey stomach" if exgurgitation from the mid gut occurs. Furthermore, whole extracts of the "honey stomach," containing no honey, never revealed the presence of any such enzymes. They therefore concluded that the sucrase and amylase found in the exgurgitated honey are produced by the salivary glands. Küstenmacher ('11) also found honey to possess some amylolytic action and thus concluded that the salivary glands secrete amylase since this enzyme is not present in the pollen and nectar eaten by the bees. In contrast to Pavlovsky and Zarin, Küstenmacher did not consider it necessary to assume that the salivary glands secrete sucrase since this enzyme is found in the pollen eaten. While Pavlovsky and Zarin apparently banished Küstenmacher's objection that the sucrase may have entered the "honey stomach" from the mid gut, they also swept out of existence his suggestion that the sucrase may have come from the pollen by feeding bees on an enzyme-free solution of sucrose. It still remains to be discovered, however, why honeybee adults, the salivary glands of which apparently secrete amylase, cannot, according to Phillips ('27), utilize starch or glycogen for food.

When sucrose, a disaccharid, is acted upon by sucrase it is hydrolyzed into its two component monosaccharids, l-fructose and d-glucose, and becomes "honey," or, in technical terms, invert sugar. Sucrose is dextrorotatory (i.e. rotates the plane of polarized light to the right). Invert sugar is laevorotatory (i.e. rotates the plane of polarized light to the left). This is because, though the glucose component of invert sugar is dextrorotatory, the fructose constituent is more laevorotatory than the glucose is dextrorotatory so that the algebraical effect of a solution of glucose and fructose in equal concentrations is to turn the plane of polarized light to the left instead of to the right as the mother solution, sucrose, did—hence the

term "invert sugar." The salivary glands of the bee secrete sucrase and amylase. These enzymes hydrolyze the sucrose and starch present in the nectar and which is stored within the crop, or "honey stomach." Sucrase hydrolyzes the sucrose into glucose and fructose while the amylase hydrolyzes the starch, that may be present, into maltose. The latter is split by maltase into glucose. Prior to 1917, many practical bee-keepers added small amounts of citric acid to the winter food of bees with the idea that the production of honey is thereby augmented. Zarin ('17) showed the practical value of systematic scientific research when he demonstrated that 0.1 per cent citric acid produces no increase in the rate of inversion of cane sugar and that 0.3 per cent citric acid definitely inhibits such action.

Since the mandibular glands of the honeybee begin to discharge their secretion two days prior to emergence from the pupal case, Dreher ('36) suggested that they serve to soften the cocoon.

The salivary glands (?) of the stick insect, *Dixippus morosus* (Belehràdek, '22), judging from the digestive juice which issues from the mouth and which is considered to contain products of salivary glands, secrete cellulase and a powerful amylase which is most active in alkalin solution. Reducing sugar is formed but only in alkalin solution. This juice has no action on fats and proteins.

The salivary extract of various species of the onychophoran *Peripatopsis* (Heatley '36), contains enzymes (amylase, glycogenase, protease) which act on large molecules, reducing the food to a semifluid state. This is then acted upon by the gut enzymes. The saliva of certain Coccidae (*Aspidiotus*, *Dactylopius*) and Capsidae (Smith, '26) appears to be capable of dissolving the cell walls of the plants through which the stylets penetrate and hence evidently contains a cellulase. The saliva issuing through the stylets of certain other Hemiptera, on the other hand, gave no evidence of such action but apparently contains a protease since the plant cell contents were destroyed over a wide area.

The enzymatic activities of the salivary glands of the cockroach (*Periplaneta orientalis*) and of several species of moth larvae (*Phalera bucephala*, *Lymantria dispar*, *Macrothylacia rubi*, and *Cerura vinula*) were studied by Dirks ('22). In all cases the glands exhibited strong amylolytic and sucrolytic properties; but there was no maltase, lactase, cellulase, glycosidase, lipase, or protease. It was suggested that the amylase and sucrase are synthesized by the salivary glands themselves and are not absorbed from the blood, for, the salivary glands were not found to possess the maltase and protease present in the blood. Furthermore, it is extremely unlikely that enzymes, as such, can diffuse into membranes. It is noteworthy that, as the above results show, the salivary glands of lepidopterous larvae which secrete silk also contain, and possibly secrete, hydrolytic enzymes. The salivary secretion of the cockroach, *Blatella germanica*, has a pH of about 6.9 (Wigglesworth, '27). This indirectly corroborates the work of Dirks since the action of most amylases is most rapid in slightly acid media. Basch (1858) was the first to show that the saliva of a cockroach (*Blatta orientalis*) has amylolytic and proteolytic activity.

The salivary glands of the adult blowfly, *Calliphora* (a non-blood-sucking fly), secrete an amylase in definitely pronounced quantity. The salivary secretion of blood-sucking insects such as tsetse fly (*Glossina*) adults and tabanid fly (*Chrysops silacea*) adults, on the other hand, do not secrete amylase nor, in fact, any hydrolyzing enzyme. The salivary glands of

Calliphora do not secrete sucrase, maltase, lactase, trypsinase, pepsinase, or peptidase, while the secretion of a lipase remains questionable (Wigglesworth, '29 and '31). Swingle ('28) could not find any hydrolyzing enzymes in the salivary glands of larval and adult oriental fruit moths (*Laspeyresia molesta*) and Roy ('37) noted that extracts of the salivary and mandibular glands of larvae of the moth, *Galleria mellonella*, show no hydrolytic action.

(*b*) *Anticoagulins*. In 1899, Sabbatani discovered that aqueous extracts of whole ticks, *Ixodes ricinus* (ectoparasitic on dogs) render the blood of vertebrates incoagulable. Both small and large ticks were potent in this respect. Blood from a dog into which a strong dose of such an extract was injected could render blood from another dog incoagulable. The production of an antibody shows that the anticoagulin is a protein. Equal dosages were found to have effects on the blood of different mammals in the following descending order: dog>cat>cow>sheep. Tick extract was also found to have similar effects on the blood of pigs and of frogs. Probably owing to the rapidity of coagulation of the blood of the poultry cock and of the pigeon, results obtained on these were negative. Sabbatani concluded that the substance preventing coagulation is an enzyme (protein), for its activity was destroyed by boiling. It was considered to be an antienzyme acting against the "filbrino-ferment" present in the blood of vertebrates. The salivary glands and gut of the tick, *Argas persicus* (Nuttall, '08), contain an anticoagulin which is inactivated by a ten-minute exposure to a temperature of 80°C. No organs in this tick were found to contain haemolysins. But Pawlowsky and Chodukin ('29) have found that the salivary glands of a tick, *Ornithodorus papillipes*, contain a substance which is capable of haemolyzing human erythrocytes.

Several papers have since appeared notifying the presence of anticoagulins in the salivary secretion of various ticks and blood-sucking flies. Thus Cornwall and Patton ('14) found the anticoagulin activity of *Musca crassirostris* to be powerful; *M. pattoni*, week; *Tabanus albimedus*, powerful; *Anopheles persicus* (mosquito), powerful; *A. fuliginosus*, powerful; and *Argas persicus* (tick), fairly powerful. They found no anticoagulin in the salivary secretion of *M. nebulo*, *M. convexifrons*, *Stomoxys* sp., *S. calcitrans* (flies) and *Cimex rotundatus* (a flea).

A thorough and noteworthy paper on the subject is that of Lester and Lloyd ('28) on the anticoagulin of the salivary secretion of the adult tsetse fly, *Glossina*. The powerful anticoagulin secreted by the salivary glands of *Glossina* delays the clotting of the blood of mammals, birds, reptiles, and amphibians. If the salivary glands are removed the fly can still draw blood normally and live for some time. After such an operation, however, large blood clots begin to form in the narrow anterior portion of the gut. The fly eventually dies merely of starvation. This shows that the gut does not contain an anticoagulin and indicates that the anticoagulin found in the intestine of *Argas* probably arrived there from the salivary glands. Lester and Lloyd noted that the hinder part of the mid gut of *Glossina* contains a coagulin which causes rapid clotting of blood in that region and thereby causes a retention of the blood in the fluid state in the mid gut thus allowing hydrolysis of the blood constituents. Both coagulin and anticoagulin have the properties of enzymes (proteins) in that they are destroyed by heat; the coagulin, being the more thermostable, is rendered inactive at 90°C. They are soluble in water, dilute salt solutions and dilute ethyl alcohol, but are quite insoluble in ether and absolute alcohol and are pre-

cipitated by half saturation with ammonium sulfate.

The mechanism of blood coagulation in vertebrates is commonly conceived to proceed thus:

$$\text{(a) Thrombokinase (enzyme)} + \text{thrombogen} \xrightarrow{\text{(Ca salts)}} \text{thrombin}$$
$$\text{(b) Thrombin} + \text{fibrinogen} \rightarrow \text{fibrin} \downarrow$$

At which points in the above reactions does the anticoagulin act? Lester and Lloyd found that the coagulin in the mid gut will not coagulate decalciated blood. They therefore suggested that the salivary anticoagulin is an antithrombokinase (antikinase) and that the coagulin in the hind intestine is akin to thrombokinase (kinase) but is not inactivated by the salivary anticoagulin.

Certain blood-sucking insects, e.g. *Stegomyia fasciata*, *Anopheles bifurcatus* (Yorke and MacFie, '24) and the tick fly *Hippobosca* (Wigglesworth, '30, personal communication from L. Lloyd), have no anticoagulins. At least in *Hippobosca*, an anticoagulin is unnecessary since the animal "spends nearly all its life upon the back of its host, sipping a little blood whenever it desires." Furthermore, it has no crop and "clotting in its proboscis" must be prevented simply by cleansing it with saliva after the meal (Wigglesworth, '30).

The adaptive significance of the presence of erythrocyte agglutinins in the salivary secretion of various Diptera (Yorke and MacFie) is as yet unascertained.

2. "*Silk*"

"Silk" is any fine, glossy, fibrous substance. Thus, a type of artificial silk is produced by allowing a solution of celloidin to pass through fine pores. Under this topic only silk produced by labial glands will be treated. This includes the silk produced by hymenopterous, lepidopterous and some coleopterous larvae and also by certain dipterous larvae such as *Simulium* and *Micetophila*. In all these cases the silk is used in the manufacture of a cocoon for pupation. Spiders and ant-lions produce silk from glands situated in other parts of their bodies. Of the silk produced by *labial* glands only that manufactured by the silkworm has been subjected to rigorous physico-chemical analyses. It is hence impossible to say whether the silk produced by the various species is similar. It is a matter of common observation, nevertheless, that even the silk produced by different species of moths is not identical in texture or color.

(*a*) *Physical properties of silkworm* (*Bombyx mori*) *silk*. The histology of the silk glands of this domesticated insect is the main subject of noteworthy papers by Helm (1876), Gilson (1890), and Lesperon ('37). These glands disappear during metamorphosis (Malpighi, 1669). Silk, on leaving the spineret of a larva, is soft but rapidly hardens. It consists of two concentric cores of "fibroin" cemented together and covered with a "gum." It is the "fibroin" which gives the finished or "soft silk" of manufacture its pearly white luster. If the natural gum is left on during commercial manufacture the silk is termed "hard silk" by sericulturists. The gum is usually removed by mechanical action and soaking in warm water. Silk without gum is known as "soft silk." The maximum diameter range of silk fibers is 0.0009–0.0023 cm. A single fiber has the great tensile strength (stress to produce rupture) of 3 to 5 $\times$ 10^9 dynes/sq. cm., extending considerably before breaking. Hence the durability of silk clothes. Under limited tensions silk will revert to its original length and, therefore, possesses some elasticity. The specific gravity of a fiber is 1.3 and is thus somewhat heavier than water. Silk has a low thermal and very low electrical conductivity and is hence used as an insulator in human economy.

(*b*) *Chemical properties*. The product obtained after treating silk with dilute

alkali or hot water was called "fibroin" by von Mulder, in 1836, and "sericin" by von Cramer, in 1865. The amino acid, serin, was first obtained by von Cramer from the hydrolysate of silk fibroin, in which serin is present in large amounts. Hence the name of this amino acid (L. *sericum* silk). Von Mulder's indefinite term has been retained since "soft silk" is a more complex material than serin, and because "sericin" is liable to be confused with serin. Furthermore, "sericin" is sometimes synonymized with not known to be synthesized by animals (for a possible exception see Jezewska, '26) and Demianowski has found more tryptophane in the silk of weak or "unhealthy" larvae than in that of sound individuals. Apparently, adequate regulation of the secretion of tryptophane is not present in weak larvae. The fibroin contains 0.32 per cent ash in terms of dry weight and 5.1 per cent water (Abderhalden and Behrend). The *Encyclopaedia Britannica* ('32) on the other hand, states that, under ordinary atmospheric conditions, fibroin contains 11 per cent water. The empty cocoon of a silkmoth, *Bombyx mori* (Kellner, 1884) contains 12.5 per cent water. But the water content of silk soon after and during its secretion is very probably higher than that.

TABLE 1

Analysis of monoamino acids secreted by Italian and Chinese larvae of Bombyx mori

MONOAMINO ACID		ITALIAN LARVAE FISCHER AND SKITA	CHINESE LARVAE ABERHALDEN AND BEHREND
Neutral aliphatic amino acid	Glycin	36.0	37.5
	d-Alanin	21.0	23.5
	l-Serin	1.6	1.5
	l-Leucin	1 to 1.5	1.5
	l-Phenylalanin	1 to 1.5	1.6
	l-Tyrosin[1]	10.0	9.8
Heterocyclic amino acid	l-Prolin	Present	1.0
Acid amino acid	l-Aspartic	Present	0.75
	l-Glutamic	0.0	—

[1] "In view of the high tyrosine content of silk it was of interest to examine quantitatively the tyrosine intake of the silkworm and compare it with that of the silk produced. The tyrosine intake in mulberry leaves ingested by the silkworms (*Bombyx mori*) was found to exceed the output of tyrosine in silk and contained groups; hence, there is no need to postulate a mechanism for the synthesis of tyrosine." (Holtzmann '36.)

the "gum." Fischer and Skita ('01) and Abderhalden and Behrend ('09) made quantitative studies on the monoamino acids yielded upon hydrolysis of silk "fibroin" produced by the larvae of *Bombyx mori*. The former workers analyzed silk secreted by Italian larvae, and the latter, that secreted by Chinese larvae. Their values are close and are expressed in percentages of the dry weight of the "fibroin" (Table 1). Demianowski ('28) has noted the presence of the diamino heterocyclic acid, tryptophane, in silk. This biologically valuable amino acid is

X-ray examination shows that fibroin is crystalline. This, of course, would be expected. Fibroin is soluble in cold concentrated mineral acids and in concentrated KOH or NaOH from which it may be reprecipitated by neutralization. It may thus be a heterogeneous albuminoid protein.

The gum, or gelatin, is, in contrast to the fibroin, extremely low in glycin content but higher in serin content (5.4 to 6.6 per cent serin of dry weight). "The analyses of silk gelatin account for only 20 to 40 per cent of the amino acids which are present" in it (Gortner, '29). Fischer and Skita ('01) have made the statement that silk gelatin is, in contrast to the fibroin, rich in diamino acids. The "gelatin," or "gum," ranges between 15 and 20 per cent, by weight, of the raw silk (Gortner).

(*c*) *The formation of silk.* Machida ('27) has attempted to localize the region in the salivary glands of *Bombyx mori* which secretes the fibroin and that which secretes the gum (or "sericin," as he terms the latter). Portions of the salivary glands of third and fourth larval instars were dissected out. Stained and sectioned preparations were made of the salivary glands of operated mature larvae and adults. When acid fuchsin and methyl green were used the fibroin was stained blue and the gum purple. The quantity of fibroin in the middle division of the salivary glands was thus found to vary directly with the size of the attached posterior division. When the posterior division was separated from the middle division the latter division lacked gum but contained fibroin. The experiments indicate that gum is secreted throughout the whole length of the middle division and fibroin in the posterior division only.

"The silk is not actually pushed out of the gland by the activity of the gland itself. It is removed by the silkworm who, having fixed the thread to some object, moves away and so pulls out the thread of silk."

Does the silkmoth larva, before spinning, have all the monoamino acids contained in the fibroin or do the silk fibers undergo later changes? An attempt at answering this question was made by Abderhalden and Dean ('09). It is desirable, in producing the required demonstration, to remove and analyze only the silk glands since, while the whole body may possess all the amino acids found in silk fibroin, the salivary glands may not contain or secrete them. Abderhalden and Dean found the isolation of the silk glands very tedious and so resorted to analyzing whole larvae. In the larvae, as in the silk, glycin and alanin ranked foremost. Glutamic acid was present in the larvae but absent from the silk fibroin. Abderhalden and Weichardt ('09) analyzed the monoamino acid concentration of mature larvae and of adult *Bombyx mori* immediately after emergence. The results (Table 2) are expressed in per cent of the dry weight of fibroin alongside those from larvae about to pupate.

TABLE 2

Analyses of monoamino acids of mature larvae and of adult Bombyx mori

MONOAMINO ACID	LARVA	ADULT
Glycin	10.2	3.5
Alanin	8.7	3.2
Valin	1.7	1.7
Leucin	4.8	8.5
Aspartic acid	1.6	2.7
Glutamic acid	3.5	5.7
Phenylalanin	2.4	2.7
Tyrosin	4.3	1.6
Prolin	1.5	4.0

Leucin, aspartic acid, phenylalanin, and prolin are present in relatively greater amounts in the adult. It is a pity that Abderhalden and Weichardt did not make their analyses on newly formed pupae instead of on newly emerged adults. Their results then would have produced evidence for what they were trying to find, namely, if the monoamino acids of the fibroin are discharged directly as such

by the larvae. Future work along such lines should make analyses of the content of individual monoamino acids of isolated salivary glands removed from larvae shortly before spinning and of the individual monoamino acid content of newly pupated silk worms. The results of Abderhalden and Dean and of Abderhalden and Weichert do show one thing, however, and that is, that it is not *necessary* to assume that any of the monoamino acids present in silk are produced subsequent to the discharge of the silk.

Oku ('29–'35) showed that the various cocoon colors (white, yellow, green, orange, red, etc.) are due to Mendelian races. The yellow color, which is most common, is due to xanthophyll ($C_{40}H_{56}O_2$; melting point = 193°C.). The fading of color is due to the oxidation of xanthophyll to $C_{40}H_{56}O_{15}$ (melting point = 90°C) which, because of its lower melting point and relatively high volatility gives cocoons their well known odor. The xanthophyll from cocoons and mulberry leaves is identical (Oku) and Jucci ('30, '36) and Buonocore and Malucelli ('34, '36) indicated that the yellow pigment of the blood is absorbed by the silk glands and thus gives silk its color. The strong evidence for this was corroborated by Malucelli ('35, '36) who found that the salivary glands are permeable to carotinoids. The red color is also due to a xanthophyll and the green to a pigment termed by Oku bombycin ($C_{20}H_{19}O_7N$). The latter is not present in mulberry leaves but is considered to be derived from the isoquercitrin of these leaves.

F. SILK FROM GLANDS OTHER THAN LABIAL

1. *Insects*

Embiids have silk glands and silk orifices in their fore legs (Weber, '33). Berlese is cited by Weber as having observed silk glands in the posterior end of the abdomen of coccids.

A most remarkable instance in this respect is that offered by the neuroptera where certain cells of the middle portions of the Malpighian tubes of the larvae are so modified as to be silk-secretory. The first case of this kind was described by Anthony ('02) in the neuropteron, *Sisyra*. The cells which produce the silk (present in the middle portion of the Malpighian tubes) are much larger than ordinary Malpighian tube cells, are vacuolated, and have the branched nuclei characteristic of the silk glands of *Bombyx mori*. These cells degenerate during the pupal period and are not present in the adult. The condition in the neuropteron *Myrmeleon formicarius* (Łoziński 'II, '21) is even more interesting since, at the approach of pupation, the excretory cells themselves, throughout the Malpighian tube, hypertrophy markedly and their nuclei branch out so that the cells eventually appear like regular silk-secreting cells. When spinning is over the nuclei decrease in size by losing particles into the cytoplasm and the cells once more become excretory. The silk passes to the exterior through the hind gut and through a spinneret present at the terminal part of the alimentary canal. Physico-chemical studies have not been made upon this silk.

2. *Spiders*

(*a*) *Properties*. (i) The "drag-line". We have Benton's ('07) as the sole physical study, from a quantitative standpoint, on the properties of spider silk. He says that his finding of a spider thread of extraordinary thickness (0.01 cm. in diameter; 2.5 meters long) induced him to measure its properties. The thread was composed of several hundred component fibers, each of about 0.005 cm. in diameter,

adhering very loosely. The mean value of the tensile strength was 1.8×10^9 dynes/sq. cm.; this value is close to that of *Bombyx mori* silk fiber (3 to 5×10^9 dynes/sq. cm.). The elongation at rupture was about 20 per cent of the original thread. The elongation produced, however, varied from day to day probably, as suggested by Benton, due to variations in moisture content. The specific gravity was 0.66, or about half that of *Bombyx* silk and two-thirds that of water, which suggests that air is probably entrapped in the silk fibers of spiders. In fact, the low specific gravity of spider silk helps spiders, after the manufacture of a tuft of silk, to soar in the air. The spider thread that has been described above was probably a "drag-line" thread. Comstock ('12), however, stated that drag-line threads, while comparatively large, are usually composed of only two fibrillae and not of several hundred. As its name implies, the "drag-line" thread is that which is secreted by spiders as they move from place to place. They also secrete such a thread when dropping from elevated positions and form the foundations of orb webs with such (Comstock).

TABLE 3

Chemical analyses of spider's silk

Glycin	35.13
d-Alanin	23.4
l-Leucin	1.77
l-Prolin	3.68
d-Glutamic acid	11.7
l-Tyrosin	8.1
Arginin	5.24
NH_3	1.16
Total	90.4

The only chemical analyses of spider's silk are, as far as I know, those of Fischer ('07) on the large spider, *Nephila madagascariensis*. The results are expressed in per cent of dry weight in Table 3. The composition is similar to that of silkworm silk except for the relatively high glutamic acid content (silkworm silk having none) and the greater relative content of prolin. Unlike *Bombyx* silk, there is no serin or phenylalanin.

(ii) The "viscid thread" of Comstock is the spiral line forming most of the orb of orb webs. It is capable of far greater stretching than the 20 per cent value for the drag-line. When touched lightly it adheres. Its considerable elasticity prevents its breaking and makes it a suitable trapping portion of the web.

Figure 2 is a drawing from a photograph taken from Comstock's spider book showing a viscid thread under enlargement. It is composed of an axis thread consisting of two strands and of a series of spherical drops borne upon such. The axis forms the elastic element and the drops form the sticky portion. Comstock noted that the viscid, or sticky, silk is secreted on the axis in a continuous sheath, or cylinder, but breaks into drops immediately the axis is fastened to another radius of the web. The axis is then released from tension with the result that there is a massing of the viscid coat in the formation of drops. Why the viscid layer should mass into several drops and not into a single large drop, why these drops should be regularly spaced cannot be completely explained at present. It will be noted that small and large drops alternate. This may be "explained" by supposing that, as the viscid mass breaks into large drops of equal volume, a little remains over and this little becomes the small drop between the two large drops. Similar surface tension phenomena have been analysed by Guye and Perrot ('03) and Hauser *et al.* ('36).

(iii) "Attachment discs" are composed of silk which attaches the drag-line at intervals to objects (Comstock).

(iv) "Hackled bands" are flat and ribbon-like, and are composed of two parallel threads covered by an amorphous sheath (Comstock).

(*b*) *Production.* "The glutinous fluid of which the thread or web of spiders is drawn", said Lister (1671), "is contained in a pair of undulated receptacles in the abdomen". Comstock ('12) has listed seven known types of silk glands in spiders. Three types of glands have been found in all species and a fourth is wanting in only two families.

Many spiders have the capacity of "shooting" out the discharged silk. When such a mass of silk is attached to the spider it may be carried aloft by wind (Ray, 1670; Lister, 1671; Bon, 1721; Comstock, '12). The wind may fasten the threads to some nearby object or, in the other extreme, carry the spiders hundreds of miles from land where they may be met by ships (Comstock).

How certain spiders manage to form orb webs of exquisite symmetry as yet requires thorough analysis. A step in this direction has been made by Peters ('36–7).

FIG. 2. SPIRAL THREAD FROM THE ORB-WEB OF ARANEA

[From a photomicrograph by John Henry Comstock in *The Spider Book* (copyright 1912), through the courtesy of Doubleday, Doran and Company, Inc.]

G. NAUPLIUS EYE SECRETION

Kollmann ('24) found that the single median eye of the nauplius stage persists in the adults of phyllopod Crustacea in a rudimentary state. The retina of this eye was interpreted as being, in the adult, glandular in appearance even though still connected with the supraesophageal ganglion. Kollmann did not determine whether this eye has the photoreceptive functions, which it possesses in the nauplius larval stage, but there were no rhabdomes.

H. HORMONES

(*a*) *From the eyestalks of Crustacea.* It is probable that the cells secreting hormones in the eyestalks of Crustacea, which cause pigment contraction, are modified hypodermal cells (Koller, '27, '29).

(*b*) *From the oenocytes.* These are relatively large cells of ectodermal origin found in insects and which may be confined solely to the hypodermis or, also, be present in the haemocoele, depending upon the species. In the bug, *Rhodnius* (Wigglesworth, '33), they are newly formed at each molt, except the last, from undifferentiated cells lodged in the hypodermis. In this bug they reach their maximum size just before the new cuticle is laid down after each molt. They, unlike the exuvial glands, persist in the adult stage. After the feeding of the adults they become active in the females but very little so in the males. Judging from their behavior under these particular conditions, Wigglesworth suggested that the oenocytes may be involved in the synthesis of some of the non-chitinous constituents of the cuticle and in the synthesis of the egg shells.

(*c*) *From the corpora allata.* The corpora allata of insects are usually two small whitish bodies on either side of the stomodeum behind the supraesophageal ganglion and are innervated by the stomodeal nervous system. In some cases they are united into a single body on the dorsal

surface of the stomodeum directly behind the supraesophageal ganglion (Maloeuf, '33). According to the Snodgrass ('35), so far as known, they occur in all insects and are included in this section because they are of ectodermal origin. Wigglesworth ('34a, '34b, '35) has indicated, in *Rhodinus*, that they are ductless glands which secrete at least two hormones which initiate molting, inhibit the onset of metamorphosis, and induce egg formation. By noting cyclical changes, Burtt ('37) indicated and, by transplantations, Hadorn ('37 a, b) demonstrated that the "ring gland" (corpus allatum) of flies is the normal agent which induces the metamorphosis of these creatures.

On the other hand, Caspari and Plagge ('35), Bounhiol ('36 a, b), and Plagge ('38) have, as a result of the use of transplantation and without overlooking the existence of the known critical period, came to the conclusion that the brain itself and not the corpora allata induce the metamorphosis of moth larvae (*Sphinx ligustri*, *Deilephila euphorbiae*, *Bombyx mori*). Weed ('36 a, b; '37) found that complete elimination of the corpora allata from grasshoppers at any time during the last larval stage does not prevent the final molt into the adult. This last evidence, however, does not speak either way since the critical period is not known and since there may have been, remaining from the penultimate molt, an adequate amount of molting hormone in the blood. Weed has nevertheless demonstrated that the corpora allata of the grasshopper are essential for complete growth of the oocytes and for the occurrence of the oviducal secretion which mutually attaches the eggs into a "pod." It is noteworthy that Schrader ('38) could find no evidence of a secretory function in the cells of the brain of the moth, *Ephestia kühniella*, at any time but, rather, observed that the corpora allata of this insect display secretory activity during metamorphosis.

1. LIGHT PRODUCTION

Under this topic only light-producing cells of ectodermal derivation will be described. Koch ('27) dug out of the soil a centipede, *Scolioplanes crassipes*, and found that it emitted an intense green light from its sterna (Fig. 3). When it moved it left behind it fluid droplets (Fig. 4A), exactly corresponding to the "pores" of its sterna, which emitted green light. This shows that both the luciferin and

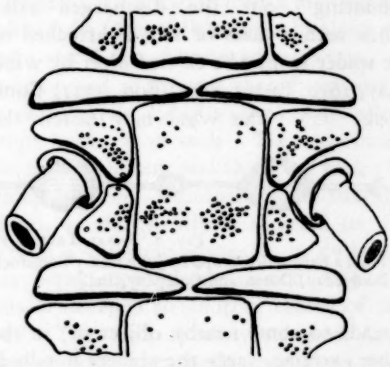


FIG. 3. STERNA OF SCOLIOPLANES CRASSIPES
The pores of the unicellular light organs are on the sterna of the trunk segments. 41.3×. After Koch.

the luciferase is secreted to the exterior. This would require a perforation at some point in the membrane of each secreting cell, since luciferase is a complex protein. Each light organ of this animal is a large hypodermal cell 140μ long, 45–70μ in diameter, and with a relatively small nucleus 5μ in diameter (Fig. 4B). The so-called "pores" are the external appearance of a thin invagination of the sternal cuticle into each light-producing cell. Similar conditions are present in *Geophilus linearis* and other members of the group Geophilidae of the Chilopoda.

Sudden submersion in water, a weak in-

duction current, chloroform, or a rise in temperature of 10°C. stimulated the production of light in *Scolioplanes*.

The organs are equally developed in both sexes and luminesce all the year round and not only, as some have believed, during the breeding season. The fact that all the Geophiloidea are eyeless also indicates that luminescence in these forms does not serve for sex attraction (Cook). The significance of the light producing cells in the economy of their possessors is indicated in the following topic.

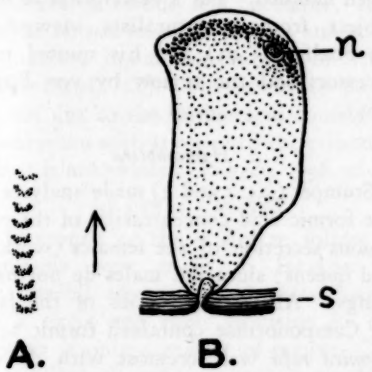


FIG. 4. A. CRAWLING LIGHT TRAIL OF THE CENTIPEDE, SCOLIOPLANES CRASSIPES, 4×. B. UNICELLULAR LIGHT ORGAN OF SCOLIOPLANES, 550X
n, nucleus; *s*, sternum. (Both after Koch.)

Certain Collembola (Heidt, '36) secrete a luminescent fluid to the exterior, the luminescence of which was shown not to be due to bacteria. Phylogenetically, it is of interest to note that the luminosity of certain terrestrial oligochaetes (Walter '09) is produced by the secretion of hypodermal glands.

J. HYDROCYANIC ACID

Guldensteeden-Egeling (1882) showed that the diplopod *Paradesmus gracilio* secretes benzaldehyde-free hydrocyanic acid. The repugnatorial glands which produce the secretion "open," according to Weber (1882), near the median dorsal line of certain segments and it is only from these segments that the characteristic odor of HCN is diffused. Wheeler (1890) noted that *P. virginiensis* acts in the same manner when roughly handled since the Prussian blue test for the —CN radical was positive.

It has been mentioned above that the groups Geophiloidea of the Chilopoda have ventral unicellular glands the secretion of which is luminous and leaves a trail. Since all Geophilidae are eyeless this luminosity cannot be supposed to serve for sex attraction. The luminous secretion has the odor of HCN (Cook) so that the significance of the light-producing cells of these animals appears to be repugnatorial. Luminosity, therefore, apparently has no adaptive significance in these cases and is merely an inevitable phenomenon arising from established physiological processes.

K. CAMPHOR

This substance is a benzol derivative with a ketone group and its detection among the synthetic secretory products of animals would be an extreme exception.

In 1900, Cook detected the odor of camphor from secretions of hypodermal glands of the terga of the trunk segments posterior to the first four trunk segments of the millipede, *Polyzonium rosalbum*. The camphor is discharged upon mechanical stimulation and may be exuded from the pores in thin milky threads which harden on exposure to air. No actual analyses, other than by smell, were made of this substance, but the statement of Oscar Loew was obtained that "there is no substance recorded with an odor that is likely to be mistaken for that of camphor." Cook has noted that another order of diplopods, the Merochaeta, secretes hydrocyanic acid from glands which are apparently homologous with the

camphor glands in other forms. These glands are apparently protective, for, in general, diplopods are comparatively immune from mites and other parasites which commonly attack animals of similar habitats.

Cook has shown that these animals will soon die (presumably of their own camphor fumes) when sealed in a small bottle and therefore are not immunized against their own toxins. Since camphor is not a protein and since an antitoxin can be produced by the body only against a substance which possesses a protein grouping, it is clear why the animals possess no antitoxin for the poison they secrete. In this respect they differ from scorpions, spiders, and centipedes, the blood of which apparently contains the respective antitoxins for the toxins secreted.

L. FORMIC ACID

1. Lepidoptera

The cocoons of many Lepidoptera are hard and horny in texture. In 1897, Latter found that larvae of *Dicranura vinula* have thoracic glands which open, by an orifice, at the prothoracic sternum. These glands were noted to secrete formic acid and thus give the silk of the cocoon its characteristic horny texture. The freshly made cocoon is consequently strongly acid when still moist. The silk threads in contact with the walls of a glass container on which sodium carbonate had been painted remained loose and soft while the threads in the interior of the cocoon became horny as usual. Adding formic acid to the silk glands caused the whole mass to swell and set in a firm and nearly transparent jelly. When this jelly was exposed to the air it shrank and yielded a hard horny mass very closely resembling a portion of a cocoon in texture and appearance. The cocoon of *Dicranura* is, in this way, made very tenacious and waterproof. Presumably, the formic acid is normally applied to the silk fibers as the the latter are secreted and these harden on contact with the air. The silk glands of *Lymantria cossus*, on the other hand, remained flaccid when treated with formic acid thus showing that the occurrence is not general among cocoon-spinning Lepidoptera. The fluid of *D. vinula* and *D. furcula* is 40 per cent formic acid (Poulton, 1887) and is discharged by the larvae when handled. For a description of this subject from a naturalists viewpoint, see Shelford ('03) and his quoted predecessors and the review by von Fürth ('03).

2. Hymenoptera

Stumper ('22 a and b) made analyses of the formic acid concentration of the poisonous secretion of the females (workers and queens) since the males do not have stings. All eleven species of the family Camponotinae contained formic acid. *Formica rufa* was foremost with the extraordinary value of 18 per cent formic acid. *Lasius fuliginosus* was lowest with a value of 2.3 per cent. The formic acid content of the venom secretion of *F. rufa* varied from 21.35 to 72.80 per cent. Probably atmospheric moisture influences the amount of water in the secretion. In fact, Melander and Brues ('06) had found that ants of a given species kept in very dry weather have a higher concentration of formic acid in their secretion than those under usual conditions.

A temperature relationship of the amount of formic acid secreted was noted by Stumper who obtained a Q_{10} value of 2.16 within ordinary temperature range. This implies that for every rise of 10°C. (within normal limits) the amount of formic acid present in the venom secretion

is more than doubled. This closely corresponds with van't Hoff's value of ca.2 for the speed of chemical reactions.

In no case did Stumper find formic acid in the bodies of worker ants of the families, Myrmicinae and Dolichoderinae. The harmful effects, produced on man, of the venom of the latter was, therefore, ascribed to some other unknown substance. All the free acid in the liquid of the poison glands (situated in the posterior end of the body) of queen and worker *Formica rufa* and *Cataglyphis bicolor*, with the exception of possible negligible amounts, is formic acid (Stumper, '22c).

The poison reservoir of bees and wasps contains a liquid that is acid to litmus (Heselhaus, '22). The honeybee poison is not due to the formic acid constituent since when such is removed the poisonous effect is not reduced (Langer, 1896, 1899).

M. OTHER "TOXINS"

In several of the works to follow no attempts were made to localize the anatomical source and chemical nature of a toxin and their inclusion in this review is only a matter of course. The terms "toxin" and "venom" *are capable of wide application since most foreign proteins are harmful, in a greater or lesser degree, and many rupture the red blood corpuscles of vertebrates*. A rigorous study of the chemical nature of the poisons *secreted* by invertebrates awaits the future. For a review of the natural history of this subject see von Fürth's ('03) book. The treatises on venoms by Calmette ('08) and Phisalix ('22) have a great deal that is interesting and yet much which should be subjected to test by modern methods.

1. Bees and wasps

Phisalix (1897 a, b, and c) injected a glycerin extract of whole wasps (*Vespa crabro*) into the thigh of a guinea pig. The result was lowering of the temperature of the guinea pig through 4°C. for about 36 hours and accompanied by local swelling. When injected in suitable amounts the liquid from the poison vesicles of wasps was found to exert an antagonistic effect on viper venom (species of viper not stated). Death of the guinea pig under such conditions was either prevented or retarded. The "toxin" of this wasp is not destroyed by heating at 120°C. for 20 minutes. After such treatment it will still immunize versus viper venom. It is soluble in ethyl alcohol and in chloroform. Tests for alkaloids in such solutions are negative. The alcoholic precipitate of the fluid in the poison reservoir of the wasp produces no symptoms and has no immunizing power. The "toxin" is, therefore, not an alkaloid nor a protein. Phisalix ('05) injected 1 cc. of a distilled water extract of bees' eggs (concentration and species not stated) into the thigh of a sparrow. The leg became paralyzed and death resulted in three days. Phisalix concluded that in bees, as in vipers, venom accumulates in the ovules. There is, however, among spiders, no relationship between the "venom" in the eggs and that of the poison glands. This may also be true for bees.

2. Aphids (Pelargonium sp.)

Dewitz ('15) found that 1 gm. (wet weight) of this plant louse will rupture the red blood corpuscles of 25 cc. of defibrinated and undiluted ox blood.

3. Aquatic beetles

Portier ('09) concluded that *Dytiscus* larvae must secrete a poison which is rapidly fatal to larger prey than themselves e.g. small fish and salamanders.

4. Centipedes and millipedes

Lithobius forficatus is apparently immune to the "poison" in its mandibular glands

because of the presence of an antitoxin in the blood. Levy ('27) seems to have demonstrated the presence of such an antitoxin by injecting blood of the centipede into crayfish which had been bitten by it. It was similarly demonstrated that the blood of *Lithobius* is antitoxic to the toxin of a centipede belonging to another genus. In 1913 Corson-White reviewed the investigations demonstrating that poisonous reptiles are immune to their own poison and more or less so to the poison of other species and that nonpoisonous reptiles are relatively resistant to the poison of poisonous reptiles. The fact, however, that she could not demonstrate the presence of an antibody in the blood of the Gila monster, *Heloderma suspectum*, makes it necessary to treat Levy's work with caution until confirmed.

The poison of *Lithobius forficatus* (Karlinski, 1883) contains formic acid or an aldehyde. The toxic action of the millipede *Iulus terrestris* (Béhal and Phisalix, '00) poison is akin to that of quinone. Liebermann's quinone test was positive but there was not sufficient material to isolate and analyze the quinone. When *I. terrestris* (Phisalix, '00) is held it rolls up and discharges a yellow penetrating fluid with a piquant odor through the orifices of ventral hypodermal cells.

Testing the effects on himself and on rats, Baerg ('24, '34) showed that *Lithobius mordax*, *Theatops spinicaudus*, *Scolopendra heros*, and *S. polymorpha* (centipedes) are harmless. In fact, Cornwall believes that the "venom" of a centipede serves principally as a digestive fluid (Pierce, '21).

5. Spiders

The poison glands are situated in the anterior part of the body and open near the tip of the claw of the chelicera of the corresponding side. The glands lead to a poison reservoir which is surrounded by muscle fibers. The poison of most spiders is effective only in causing the paralysis of captured insects and small arthropods.

In 1693, the Italian physician, Sanguinetti (Kobert, '01), allowed himself to be bitten on the arm by tarantulas in the presence of a witness. The results were no greater than a mosquito or ant bite. In some cases secondary infection set in. In fact, the large tarantula, *Trochosa singoriensis*, would not bite even when induced to do so. Concerning the notorious tarantula bite, a physician, Cirillo, told the Royal Society of London, in 1770, that ". . . neither men nor animals (meaning large mammals), after the bite, have had any other complaint, but a very trifling inflammation of the part, like those produced by the bite of a scorpion, which go off by themselves without any danger at all." The bite of the tarantula has been supposed to be cured by music. "Every year," Cirillo went on, "this surprising disorder loses ground, and doubtless in a very little while it entirely loses credit."

In 1882, Blackwell allowed himself to be bitten by seven different species of spiders (apparently all natives of Great Britain). The bite produced no effects on himself nor on spiders of the same or other species, beyond those similarly caused by a pin. Bites had destructive effects on insects but not with the virulence or rapidity that had been supposed. Concerning the notorious black widow spiders (*Latrodectus mactans* mature females) an early missionary, Sahagun, wrote: "There are some spiders in this country, they are black and have a reddish tail. The stings cause great fatigue for three or four days, although they do not kill with their sting" (Curran, '37). "I have endeavored," wrote Comstock ('12), "to trace to their source some of the newspaper stories of terrible results following the bite of a spider; but have not found a bit of evidence that would connect a spider with the injury in any one of the cases investigated." He assures us that there is no spider in the northern part of the United States which is capable of producing injury to a human being by a bite. W. Riley and Johannsen ('15) adopt the same attitude. C. Riley and Howard (1889) had recognized an exception and considered that certain fairly small spiders of the genus *Latrodectus* (black widow) may "exceptionally and depending upon exceptional conditions, bring about the death of a human being" —a thoroughly non-committal statement based on rather meager facts (Kobert's, '01 experiments on the effects of extracts of the whole cephalothoraces of the spiders on cats). The statements of Kobert ('01)

and D'Amour *et al.* ('36) that the poisonous principle in the secretion of *Latrodectus* is a protein are not conclusive since they used extracts of the whole gland. In fact, Kobert thus found the "venom" not only in the poison glands but also in other tissues and even in the eggs. D'Amour *et al.*, however, state that the venom of the eggs is different.

In certain contrast to the above direct quotations Bogen ('32) and D'Amour *et al.* ('36) have pointed out that the bite of mature females of *Latrodectus mactans* (the immature females and males are relatively or quite harmless to rats even though they possess poison glands) often produces excruciating pain and muscular spasms throughout the trunk which last for about three days (see also Baerg, '22 and Blair, '34) and that the bite has, in some cases, proved fatal to human beings. The extent of the effect, of course, varies with the amount of poison injected and with its concentration. When given as food, however, the poison glands are quite harmless even to small animals such as birds and rats (D'Amour *et al.*). *L. mactans* occurs throughout the United States and it has been observed in many parts of Canada. It is quite common in the southwestern states where it often proves a pest.

The experiments of Blackwall (*loc. cit.*) and of Levy ('27) indicate that spiders have an antitoxin in their blood which is also effective against spiders of another species. Sachs' ('02) "antitoxin" versus spider venom is of no importance because whole-spider extract was used.

Erythrocytes of the rat and rabbit are very sensitive to extracts of the house spider (*Araneus diadematus*), undergoing complete rupture; those of the mouse, goose, and man are less sensitive; and those of the guinea pig, horse, sheep, and dog are apparently insensitive (Dewitz, 15).

Egg extracts of *Araneus erythromela*, of *A. amaurophyla*, and of *Latrodectus poliostoma* (Houssay, '16) have powerful haemolytic action. The haemolytic power of the newly hatched animals was a little less than that of the eggs. Extracts of the female spiders containing eggs had haemolytic action but those of adult male spiders produced no haemolysis. Houssay concluded that haemolysis can have nothing to do with the poison secreted by the poison glands since males and females with or without eggs, paralyze captured flies with the same speed. The haemolysins are apparently proteins since they are non-dialyzable; are absorbed on animal charcoal; and are insoluble in methyl, ethyl, or amylic alcohol, benzine, chloroform, and acetone. The serum of a rabbit immunized against *L. mactans* will only neutralize the haemolysin of *L. mactans*. The serum of rabbits immunized versus *A. erythromela* or *A. amaurophyla* will neutralize the haemolysin of either. The intrageneric specificity displayed by the anti-haemolysin is further evidence for considering the haemolysins as proteins. Houssay found no haemolytic action in the eggs, young, or adults of *Lycosa poliostoma*, *Polybetes pythagorica*, *Theridion calcinatum*, and *T. uber*.

Levy ('16) corroborated one of Houssay's conclusions by showing that the "venom" of the chelicerae of spiders has no haemolytic action on rabbit, mouse, and frog erythrocytes and that it, furthermore, has no toxic action on these vertebrates. The "venom" was, however, very toxic to crayfish, producing paralysis followed by death. The toxic action of the secretion was destroyed by heat at about the same temperature as that for protein coagulation. This contrasts with the toxin of wasp venom (see above), which is not a protein. Levy showed that the toxic or haemolytic action of the eggs is not correlated with the degree of toxicity of the venom produced by the

poison glands in the chelicerae. Thus, the venom of the poison glands of *Tegenaria parietina*, a species containing no toxic substance in its eggs, is just as toxic as other species. The blood of tenerid spiders has antitoxic properties against the spider venom and this antitoxicity was, in fact, stated to be elevated by heating the blood to 72°C. We do not know how this antitoxicity is exerted. Antitoxicity could not be shown in the blood of the Epeiridae.

Levy came to the rather unwarranted conclusion that, because the toxin secreted by the poison glands of the spiders was deadly to the crayfish but harmless to the rabbit, mouse, and frog, it is specifically adapted to the destruction of arthropods—their "natural enemies"— and that the antitoxic properties of the blood of these spiders towards their own poison is because they feed almost exclusively on arthropod tissues. He, however, apparently tested the effects of spider venom on only one arthropod.

6. *Scorpions*

These include the most poisonous arthropods. Their poison glands are located at the posterior extremity of the abdomen where the secretion is discharged by way of the sting.

During the dry season, according to Barrett ('01), the sting of a given species is much more toxic than during the rainy season. Judging from observations on the effects of dryness and humidity on the formic acid concentration of the toxic fluid secreted by ants, it is very probable that this may be due to a greater concentration of the toxin during the dry season. Bites by the Egyptian species, *Buthus quinquestriatus* (Wilson, '04), are fatal in about 60 per cent of the cases under five years of age. For the most venomous Mexican species (*Centruroides suffusus*, *C. limpidus*, and *C. noxious*) see Cavarox (1865) and Baerg ('24, '34). By tests on himself and on rats Baerg (*loc. cit.*) was able to show that *Centruroides vittalus*, *C. thorelli*, *Centrurus exilicauda*, *Vaejovis variegatus*, *V. subcristatus* are almost harmless.

The large brownish-yellow genus, *Centrurus* sp., (or "alacran huero") of Mexico is perhaps the most poisonous arthropod (Barrett). Deaths caused by scorpion stings among children under six years of age were common in the Mexican states of Durango and Guerrero when Barrett wrote. Launoy ('01) allowed rats, mice, birds, frogs, and sparrows to be stung. On the whole the frogs were least irresistant but were nevertheless overwhelmed. Launoy made histological studies of the victims which died within ten minutes. In all cases the lesions were quite similar. There was extensive destruction of the glomeruli of the kidneys, vacuolization of the cytoplasm of the cells of the convoluted tubes of the kidney along with chromatolysis and karyolysis.

Levy ('27) quotes Metschnikoff as showing that the blood of a scorpion has antitoxic properties against the venom secreted.

7. *Whip "scorpions" and Solpugida*

The "poisonous" effects of *Mastigoproctus giganteus* (or "vinaigrillo") of Mexico has been described by Barrett ('01) in the following incidents:

> "At Cuernavaca I was told of a field labourer who was found dead, but *sitting bolt upright*, so great had been the nervous shock and muscular cramping from a 'vinaigrillo' sting." Comstock (1897), however, had previously written: "Although it has been stated often that their bites are poisonous, we can find no direct evidence that it is so. They destroy their prey by crushing it with their palpi." The incident related to Barrett may, therefore, be the outcome of the awed imagination of uneducated peasantry. In fact, Petrunkevitch (*In Litt.*, '37) has informed me that whip "scorpions" have no poison

glands. With reference to the whip-scorpions, "Dr. Marx states that there is neither a poison gland nor a pore in the claw of the chelicera" and Dr. A. Walter stated that the Solpugida are not poisonous and have no poison glands or pores in the fangs.

N. MATING GLANDS OF FEMALE MOTHS

Male moths are often attracted to females of their species, or to extracts of the females, from considerable distances. The female apparently secretes the volatile gas-producing liquid from certain unicellular hypodermal glands in the posterior region of the abdomen. Her abdomen is alternatively protruded and retracted when the males are being attracted (Eltringham, '33). Olfactoreption is the chief means of communication among social insects (cf. McIndoo, '28). They so distinguish between individual, sex, hive or colony, and trail odors. Scent glands are located on various parts of the body.

LIST OF LITERATURE

ABDERHALDEN, E. and L. BEHREND. Vergleichende Untersuchungen über die Zusammensetzung und den Aufbau verschiedener Seidenarten. II. Die Monoaminosäuren aus Canton—Seide. *Z. physiol. Chem.* 59: 236, 1909.

——, and H. R. DEAN. Studien über die Bildung der Seide. *Ibid.* 59: 170, 1909.

——, and W. WEICHERT. Die Monoaminosäuren des Körpers des Seidenspinners. *Ibid.* 59: 174, 1909.

D'AMOUR, F. E., F. E. BECKER, and W. VAN RIPER. The black widow spider. QUART. REV. BIOL. 11: 123, 1936.

ANTHONY, M. H. The metamorphosis of *Sisyra*. *Amer. Nat.* 36: 315, 1902.

ARISTOTELES. Engl. transl. by A. Platt, 1910: "De generatione animalium." In "The works of Aristotle," ed. by J. A. Smith and W. D. Ross, pp. 714–789, Oxford, ca. 342 B.C.

BAERG, W. J. The effects of the bite of *Latrodectus mactans*. *Z. parasitol.* 9: 161, 1922.

——. The effect of the venom of some supposedly venomous arthropods. *Ann. Entom. Soc. Amer.* 17: 343, 1924.

——. Some poisonous arthropods of southwestern Mexico. (Chilopoda and Arachnida). *Biol. Bull.* 27: 327, 1934.

BARRETT, O. W. The effects of scorpion venom. *Can. Entom.* 33: 234, 1901.

BASCH, S. Untersuchungen über das chylopoetische und uropotische System der *Blatta orientalis*. *Sitzungsber. der math.-naturwiss. Classe der kaiser. Akad. der Wiss.* 33: 234, 1858.

BÉHAL and PHISALIX. La quinone, principe actif du venin du Iulus terrestris. *Mus. d'Hist. Nat. Bull.* 6: 388, 1900.

BELEHRÀDEK, J. Expériences sur la cellulase et l'amylase de la salive chez *Dixippus morosus*. *Arch. intern. de Physiol.* 17: 260, 1922.

BENTON, J. R. The strength and elasticity of spider thread. *Amer. J. Sci.* 4th. ser. 24: 75, 1907.

BERTHOLF, L. M. The utilisation of carbohydrates as food by honeybee larvae. *J. Agr. Res.* 35: 429, 1927.

BLACKWALL, J. Experiments and observations on the poison of animals of the order Araneidea. *Trans. Linn. Soc. Lond.* 21: 31, 1852.

BLAIR, A. Spider poisoning. *Arch. of Internal Med.* 54: 831, 1934.

BOGEN, E. Poisonous spider bites. *Ann. of Internal Med.* 6: 375, 1932.

BON. Of the usefulness of the silk of spiders. *Philos. Trans. Roy. Soc. Lond.* 2(3): 382, 1791.

BOUNHIOL, J.-J. Métamorphose après ablation des corpora allata chez le ver à soie (*Bombyx mori* L.). *C. r. Acad. Sci.* 203: 388, 1936 a.

——. Dans quelles limites l'écérebration des larves de lépidoptères est-elle compatible avec leur nymphose? *Ibid.* 203: 1182, 1936 b.

BUONOCORE, C. Ricerche sulla funzione secondaria dei seritteri nel *Bombyx mori* L., eseguite mediante la loro asportazione. *Boll. Staz. sper. Gelsicolt. Bachicolt. Ascoli Piceno* 15: 1, 1936.

—— and P. MALUCELLI. Sulla colorazione die bozzoli nel baco da seta in rapporto ai pigmenti della foglia ingerita. *Ibid.* 13: 166, 1934.

BURTT, E. T. On the corpora allata of dipterous insects. *Proc. roy. Soc. Lond.* 124B: 13, 1937.

CALMETTE, A. "Venoms: venomous animals and antivenomous serum-therapeutics." *New York, Engl. Transl.*, 403 pp., 1908.

CAMPBELL, F. L. Personal communication. 1936.

CANNON, H. G. *Trans. Roy. Soc. Edinb.* 55: 807, 1928.

——. A further account of the feeding mechanism of *Chirocephalus diaphanus*. *Proc. Roy. Soc. Lond.* 117B: 455, 1935.

CASPARI, E. and E. PLAGGE. Versuche zur Physi-

ologie der Verpuppung von Schmetterlingsraupen. *Die Naturwissen.* 23: 751, 1935.

CAVAROZ, M. Du scorpion de Durango et du Cerro de los remedios. *Recueil de Mémoires de Médecine militaire,* 3: 327 (1865).

CHIBNALL, A. C., A. L. LATNER, E. F. WILLIAMS, and A. A. AYRE. The constitution of coccerin. *Biochem. J.* 28: 313, 1934.

——, and S. H. PIPER. The metabolism of plant and insect waxes. *Ibid.* 28: 2209, 1934.

——, A. POLLARD, E. F. WILLIAMS, and P. N. SAHAI. The constitution of the primary alcohols, fatty acids and paraffins present in plant and insect waxes. *Ibid.* 28: 2189, 1934.

CIRILLO, D. On the tarantula. *Philos. Trans. Roy. Soc. Lond.* 13: 46, 1770.

COMSTOCK, J. H. A Manual for the Study of Insects. *Ithaca,* 701 pp., 1897.

——. The Spider Book. *New York,* 707 pp., 1912.

COOK, O. F. Camphor secreted by an animal, *Polyzonium. Sci.* 12: 516, 1900.

CORNWALL, J. W., and W. S. PATTON. Some observations on the salivary secretion of the commoner blood-sucking insects and ticks. *Ind. J. Med. Res.* 2, No. 2.

CORSON-WHITE, E. P. p. 195 in "The Venom of *Heloderma*" by L. Loeb, *Washington* 1913.

CUÉNOT, L. Études physiologiques sur les crustacés décapodes. *Arch. de Biol.* 13: 245, 1895.

CURRAN, D. H. Item: On the black widow spiders. *Sci.* 87, no. 2207, p. 13, 1937.

DEMIANOWSKI, S. Zur Frage nach der Rolle des Tryptophanes im tierischen Organismus. *Biochem. Z.* 193: 245, 1928.

DEWITZ, J. On the poisons of plant-lice. *Ann. Entom. Soc. Amer.* 8: 343, 1915.

DIRKS, E. Liefern die malpigischen Gefässe Verdauungssekrete? *Arch. f. Naturges. Abt. A.* 88: 161, 1922.

DRACH, P. Aperçu sur les modifications subies par le squelette, avant la mue, chez les crustacés décapodes. *C. r. Acad. Sci.* 201: 157, 1935 a.

——. Phénomènes de résorption dans l'endosquelette des décapodes brachyoures, au cours de la période qui précède la mue. *C. r. Acad. Sci.* 201: 1424, 1935 b.

DREHER, K. Die Funktion der Mandibeldrüsen bei der Honigbiene (*Apis mellifica* L.). *Zool. Anz.* 113: 26, 1936.

DREYLING, L. Ueber die Wachsarbeitenden Organe der Honigbiene. *Zool. Anz.* 26: 710, 1903.

ELTRINGHAM, H. The Senses of Insects. 126 pp., *London,* 1933.

FISCHER, E. Ueber Spinnenseide. *Z. physiol. Chem.* 53: 126, 1907.

FISCHER, E., and A. SKITA. Ueber das Fibroin der Seide. *Z. physiol. Chem.* 33: 177, 1901.

FLANDERS, S. E. Wax secretions in the Rhizobiini. *Ann. Entom. Soc. Amer.* 23: 808, 1930.

FRANCIS, F., S. H. PIPER, and T. MALKIN. The *n*-fatty acids. *Proc. Roy. Soc. Lond.* 128A: 214, 1930.

VON FÜRTH, O. Vergleichende chemische Physiologie der niederen Tiere. *Jena,* 668 pp., 1903.

GASCARD, A., and G. DAMOY. Sur les acides de la cire d'abeilles. *C. r. Acad. Sci.* 177: 1222, 1923.

——. Sur les alcools et les carbures de la cire d'abeilles. *Ibid.* 177: 1442, 1923a.

GILSON, G. Recherches sur les cellules sécrétantes. I. La soie et les appareils sericigènes. I. Lépidoptères. *La Cellule* 6: 116, 1890.

GORTNER, R. A. Outlines of Biochemistry. *New York,* 793 pp., 1929.

DE GUBERNATIS, A. Zoological Mythology or the Legends of Animals. Vol. 2, 442 pp. *London,* 1872.

GULDENSTEEDEN-EGELING, C. Bildung von Blausäure bei einem Myriapoden (*Fontaria*). *Arch. ges. Physiol.* 28: 576, 1882.

GUYE, P.-A. and F.-L. PERROT. Étude éxperimentale sur la forme et sur le poids des gouttes statiques et dynamiques. *Arch. des Sci. physique et nat.* 15: 132, 1903.

HADORN, E. An accelerating effect of normal "ring-glands" on puparium—formation in lethal larvae of *Drosophila melanogaster. Proc. nat. Acad. Sci.,* Washington 23: 478, 1937 a.

——. Hormonale Kontrolle der Puppariumbildung bei Fliegen. *Naturwiss.* 25: 681, 1937 b.

HAUSER, E. A., H. E. EDGERTON, B. M. HOLT, and J. T. COX, JR. The application of the high-speed motion picture camera to research on the surface tension of liquids. *Journ. physical Chem.* 40: 973, 1936.

HEATLEY, N. G. The digestive enzymes of the Onychophora (*Peripatopsis* spp.). *J. Exp. Biol.* 13: 329, 1936.

HEIDT, K. Über das Leuchten der Collembolen *Onychiurus armatus* Tbg. und *Achorutes muscorum* Templ. *Biol. Zbl.* 56: 100, 1936.

HELM, F. E. Ueber die Spinndrüsen der Lepidopteren. *Zs. wiss. Zool.* 26: 434, 1876.

HERRICK, F. H. The American lobster. *Bull. U. S. Fish Comm.* 252 pp., 1895.

HESELHAUS, F. Die Hautdrüsen der Aphiden und verwandten Formen. *Zool. Jb., Anat.* 43: 369, 1922.

HOLTZMANN, J. The tyrosine metabolism of *Bombyx mori* (silk worm). *Biochem. J.* 30: 28, 1936.

HOOP, M. Häutungsphysiologie einiger Insekten. *Zool. Jb., Anat.* 57: 433, 1933.

HOUSSAY, B. A. Contribution à l'étude de l'hémolysine des araignées. *C. r. Soc. Biol.* 79: 658, 1916.

HUNTER, J. Observations on bees. *Philos. Trans. Roy. Soc.* 17: 155, 1792.

JAUBERT, G. F. Sur l'origine de la couleur jaune de la cire des abeilles. *C. r. Acad. Sci.* 185: 405, 1927.

JEZEWSKA, M. Les chargements de la teneur en tryptophane au cours du développement des chrysalides des mouches. *C. r. Soc. Biol.* 95: 910, 1926.

JUCCI, C. Sui pigmenti della uova dei bachi da seta. *Boll. Soc. Ital. Biol. Sperim.* 5: 160, 1930.

——. Nuove ricerche sulla colorazione dei bozzoli nel baco da seta in rapporto ai pigmenti della foglia ingerita. *Archivio zool. ital.* 22: 259, 1936.

KARLINSKI, J. Ueber die Giftdrüsen in den Kopfdrüsen der Lithobiidae. *Kosmos, Lemberg.* p. 364, 1883.

KEILIN, D., P. TATE, and M. VINCENT. The perispiracular glands of mosquito larvae. *Parasitol.* 27: 257, 1935.

KELLNER, O., T. SAKO, and SAWANO. Chemische Untersuchungen über die Entwicklung und Ernährung des Seidenspinners, *Bombyx mori*. I. *Landwirtsch. Versuchs-stationen* 30: 59, 1884.

KOBERT, R. Beiträge zur Kenntniss der Giftspinnen. *Stuttgart*, 816 pp., 1901.

KOCH, A. Studien an Leuchtenden Tieren. I. Das Leuchten der Myriapoden. *Z. Morph. Ökol. Tiere.* 8: 241, 1927.

KOLLER, G. Über Chromatophoren-system, Farbensinn und Farbwechsel bei *Crangon vulgaris*. *Z. vergl. Physiol.* 5: 191, 1927.

——. Die innere Sekretion bei wirbellosen Tiere. *Biol. Rev.* 4: 269, 1929.

KOLLMANN, M. Fonction glandulaire dans l'oeil impair des phyllopodes. *C. r. Soc. Biol.* 91: 153, 1924.

KÜSTENMACHER, M. Zur Chemie der Honigbildung. *Biochem. Z.* 30: 237, 1911.

LANG, D. and C. M. YONGE. The function of the tegumental glands in the statocyst of *Homarus vulgaris*. *Journ. mar. biol. Assoc.*, Plymouth 20: 333, 1935.

LANGER, J. Ueber das Gift unserer Honigbiene. *Arch. f. exp. Pharm. u. Pathol.* 38: 381, 1896.

——. Abschwächung und Zerstörung des Bienengiftes. *Arch. intern. Pharmak.* 6: 181, 1899.

LATTER, O. H. The prothocacie gland of *Dicranura vinula* and other notes. *Trans. Entom. Soc. Lond.* p. 113, 1897.

LAUNOY, L. Alterations rénales consécutives a l'intoxication aigne par le venin de scorpion. *C. r. Soc. Biol.* 53: 91, 1901.

LESPERON, LOUISE. Recherches cytologiques et éxperimentales sur la sécretion de la soie et sur certains mécanismes excréteurs chez les insectes. *Arch. Zool. expér. génér.* 79: 1, 1937.

LESTER, H. M. O., and L. LLOYD. Notes on the process of digestion in tsetse flies. *Bull. Entom. Res.* 19: 39, 1928.

LEVY, R. Contribution a l'étude des toxines chez les araignées. *Ann. Sci. Nat.* ser. 10, 1: 161, 1916.

——. Action antitoxique du sang de *Lithobius forficatus* L. vis-a-vis du venin de la même espèce et vis-a-vis du venin de *Cryptops anomalous*. *C. r. Soc. Biol.* 96: 258, 1927.

LIEBERMANN, D. Ueber das Wachs und die Fette der Cochenille. *Ber. deutsch. chem. Gesellsch.* 18: 1975, 1885.

——, and O. BERGAMI. Ueber Coccerylalkohol und Coccerinsäure. *Ibid.* 20: 959, 1887.

LISTER, M. On a kind of viviparons fly; together with some inquiries about spiders. *Philos. Trans. Roy. Soc. Lond.* 1: 600, 1671.

ŁOZIŃSKI, P. Uber die Malpighischen Gefäsze der Myrmeleonidenlarven als Spinndrüsen. *Zool. Anz.* 38: 401, 1911.

——. Cytologische Untersuchungen über die Umwandlung der Malpigischen Gefäsze der Myrmeleonidenlarven in Spinndrüsen und über die Spinnstoffsekretion. *Bull. intern. de l'Acad. polon. des Sci. et des Lettres, Cl. des Sci. math. et nat. ser. B, Sci. nat.*, p. 61, 1921.

MACHIDA, J. On the secretion of the silk substance in the silkworm, *Bombyx mori*, L. *J. Coll. Agr. Imp. Univ. Tokyo* 9: 119, 1927.

McINDOO, N. E. Communication among insects. *Smiths Inst. Ann. Rept.* pp. 541–562, 1928.

MALOEUF, N. S. R. Studies on the internal anatomy of the "stink bug." *Bull Soc. Roy Entom. d'Egypte* p. 96, 1933.

——. Studies on the respiration of arthropods and on the permeability of their outer integument to gases. *J. Exp. Zool.* 74: 323, 1936.

MALPIGHI, M. "Traité du ver a soie." Montpellier, 154 pp., 1669, Fr. transl. by E. Maillot 1878.

MALUCELLI, P. Sulla migrazione precoce e tardiva dei pigmenti nella ghiandole serigene de *Bombyx mori*. *Boll. Sta. sper. Gelsicolt. Bachic. Ascoli Piceno* 14: 193, 1935.

——. Ancora sulla migrazione precoce e tardiva dei pigmenti nelle ghiandole serigene del *Bombyx mori* (terza ed ultima nota). *Boll. Staz. sper. Gelsic. Bachic. Ascoli Piceno* 15: 53, 1936.

MELANDER, A. L., and C. T. BRUES. The chemical

nature of some insect secretions. *Wiscons. Nat. Hist. Survey*, Bull. 4: 22, 1906.

NUTTALL, G. H. F. The presence of anticoagulin in the salivary glands of *Argas persicus*. *Proc. Cambr. Philos. Soc.* 15: 53, 1908.

OKU, M. On the natural pigments of raw silk fibre of the domestic cocoon. I. Xanthophyll of the yellow cocoon. *Bull. Agric. Chem. Soc. Japan*, p. 81, 1929.

——. II. Xanthophyll of mulberry leaves as a source of yellow cocoon xanthophyll. *Ibid.* p. 104, 1930.

——. III. Melting point of cocoon xanthophyll. *Ibid.* 8, 1931.

——. IV. Carotin and xanthophyllesters. *Ibid.* 8, 1932.

——. V. *Ibid.* 9, 1933.

——. VI. Fading of the yellow cocoon. *Ibid.* p. 93, 1933.

——. VII. On the pigments of the green cocoon. *Ibid.* 10: 158, 1934.

——. VIII. Isoquercitrin from mulberry leaves. *Ibid.* 10: 164, 1934 a.

——. IX. Several pigments of yellow, green, and white cocoons. *Ibid.* 11: 8, 1935.

——. X. Relation between fluorescence colours of cocoons and that of natural pigments of the cocoons under irradiation with filtered ultra-violet light. *Ibid.* 11: 1253, 1935 a.

——. XI. Summary of parts I–X. *Ibid.* 11: 10, 1935 b.

PAWLOWSKY (PAVLOVSKY), E. N., and E. J. ZARIN. On the structure of the alimentary canal and its ferments in the bee, *Apis mellifica*. *Quart. J. Micr. Sci.* 66: 509, 1922.

——, and N. J. CHODUKIN. Über die Anticoaguline und andere wirksame Bestandteile der Zecke *Ornithodorus papillipes*. *Z. Parasitenkunde* 2: 90, 1929.

PETERS, H. Studien am Netz der Kreuzspinne (*Aranea diadema*). I. Die Grundstruktur des Netzes und Beziehungen zum Bauplan des Spinnenkörpers. *Zs. Morph. Ökol. Tiere* 32: 613, 1936–7.

PETRUNKEVITCH, A. Personal communication, 1937.

PHILLIPS, E. F. The utilization of carbohydrates by honeybees. *J. Agr. Res.* 35: 385, 1927.

PHISALIX, C. Antagonisme entre le venin des Vespidae et celui de la vipère; le premier vaccine contre le second. *C. r. Soc. Biol.* 4: 1031, 1897 a.

——. Ditto. *C. R. Acad. Sci.* 125: 977, 1897 b.

——. Ditto. *Bull. Mus. d' Hist. Nat. Paris* 3: 318, 1897 c.

——. Un venin volatil: sécrétion cutanée du *Iulus terrestris*. *Ibid.* 6: 385, 1900.

PHISALIX, C. Sur la présence de venin dans les oeufs d'abeilles. *C. r. Soc. Biol.* 141: 275, 1905.

PHISALIX, MARIE. "Animaux venimeux et venins." *Paris*, vol. I, 656 pp., 1922.

PIPER, S. H., A. C. CHIBNALL, and E. F. WILLIAMS. Melting points and long crystal spacing of the higher primary alcohols and *n*-fatty acids. *Biochem. J.* 28: 2175, 1934.

PLAGGE, E. Weitere Untersuchungen über das Verpuppungshormon bei Schmetterlingen. *Biol. Zbl.* 58: 1, 1938.

POLLARD, A., A. C. CHIBNALL, and S. H. PIPER. The wax constituents of forage grasses. I. *Ibid.* 25: 2111, 1931.

POLLISTER, PRISCILLA F. The structure and development of wax glands of *Pseudococcus maritimus* (Homoptera, Coccidae). *Quart. Journ. micr. Sci.* 80: 127, 1937.

PORTIER, P. Recherches physiologiques sur les insectes aquatiques. I and II. *C. r. Soc. Biol.* 66: 343; 379, 1909.

POULTON, E. B. The secretion of pure aqueous formic acid by lepidopterous larvae for the purpose of defense. *Rept. 5th. Meeting Brit. Assoc. Adv. Sci.* p. 765, 1887.

PRENTISS, C. W. The otocyst of decapod Crustacea: its structure, development, and functions. *Bull. Mus. Comp. Zool., Harvard*, 36: 167, 1901.

RAY, J. A confirmation of what was formerly printed in number 50 of these tracts, about the manner of spiders projecting their threads. *Philos. Trans. Roy. Soc. Lond.* 1: 535, 1670.

RILEY, C. V., and L. O. HOWARD. A contribution to the literature of fatal insect bites. *Insect Life, Washington*, 1: 204, 1889.

RILEY, W. A., and O. A. JOHANNSEN. Handbook of Medical Entomology. *Ithaca*, 348 pp., 1915.

ROBERTSON, J. D. Some features of the calcium metabolism of the shore crab (*Carcinus maenas* Pennant). *Proc. roy. Soc. Lond.* 124B: 162, 1937.

ROGOJANU, V. Untersuchungen über die Wachsdrüsen und die Wachsabsonderung bei den Gattungen *Schizoneura* und *Orthezia*. *Z. mikr.-anat. Forsch.* 37: 151, 1934.

ROY, D. N. On the nutrition of larvae of the bee-wax moth, *Galleria mellonela*. *Zs. vergl. Physiol.* 24: 638, 1937.

SABBATINI, L. Ferment anticoagulant de l'*Ixodes ricinus*. *Arch. ital. Biol.* 31: 37, 1899.

SACHS, H. Zur Kenntnis des Kreuzspinnengiftes. *Hofmeisters Beitr. z. chem. Physiol.* 2: 125, 1902.

SCHRADER, K. Untersuchungen über die Normalentwicklung des Gehirns und Gehirntransplantation bei der Mehlmotte *Ephestia kuhniella* Zeller

nebst einigen Bemerkungen uber das Corpus allatum. *Biol. Zbl.* 58: 52, 1938.

Schulz, F. N. Über Farbstoff und Wachs der Blutlaus, *Schizoneura lanigera*. *Biochem. Z.* 127: 112, 1922.

——, and M. Becker. Über Insektenwachse. III. Über das Wachs der Wollaus, *Pemphigus xylostei*. *Biochem. Z.* 235: 233, 1931.

Schulze, K. Die Hautdrüsen der Odonaten: Bau, Verteilung, Entwicklung und Funktion. *Zool. Jb., Anat.* 58: 239, 1934.

Schürfeld, W. Die physiologische Bedeutung der versondrüsen untersucht im Zusammenhang mit ihrem feineren Bau. *Arch. Entw.-mech.* 133: 728, 1935.

Shelford, V. A curious protective device in a lepidopterous larva. *Zoologist* 7: 161, 1903.

Smith, K. M. A comparative study of the feeding methods of certain Hemiptera and of the resulting effects upon the plant tissue, with special reference to the potato plant. *Ann. appl. Biol.* 13: 109, 1926.

Snodgrass, R. E. Principles of Insect Morphology. New York, 667 pp., 1935.

Stumper, R. Nouvelles observations sur le vénin des fourmis. *C. r. Acad. Sci.* 174: 413, 1922 a.

——. Quantitative Ameisenbiologie. *Biol. Centralbl.* 42: 435, 1922 b.

——. Le vénin des fourmis, en particulier l'acide formique. *C. r. Acad. Sci.* 174: 66, 1922 c.

Sundwick, E. E. Ueber Psyllawachs, Psyllostearylalkohol und Psyllostearylsäure (Psyllaalkohol, Psyllasäure). III. *Z. physiol. Chem.* 32: 355, 1901.

Swingle, H. S. Digestive enzymes of the oriental fruit moth. *Ann. Entom. Soc. Amer.* 21: 469, 1928.

Tower, W. L. Observations on the changes in the hypodermis and cuticula of Coleoptera during ecdysis. *Biol. Bull.* 10: 176, 1906.

Verne, J. Essai histochimique sur les pigments tégumentaires des crustacés décapodes. *Arch. Morph. génér. éxper.* 16: 157 pp., 1923.

Verson, E. Hautdrüsen bei Bombyciden. *Zool. Anz.* 13: 118, 1890.

Vitzou, A. Recherches sur la structure et la formation des téguments chez les crustacés décapodes. *Arch. Zool. exper. génér.* 10: 451, 1882.

Wachter, S. The moulting of the silkworm and a histological study of the moulting gland. *Ann. Entom. Soc. Amer.* 23: 381, 1930.

Walter, A. Das Leuchten einer terrestrischen Oligochaeten. *Trav. Soc. Nat. St. Petersb., C. r. des Séances* 40: 136, 1909.

Weber, H. Lehrbuch der Entomologie. *Jena*, 726 pp., 1933.

Weber, M. Über eine Cyanwasserstoffsäure bereitende Drüse. *Arch. mikr. Anat.* 21: 468, 1882.

Weed, Isabelle G. Removal of corpora allata on egg production in the grasshopper, *Melanoplus differentialis*. *Proc. Soc. exp. Biol. Med.* 34: 883, 1936 a.

——. Experimental study of moulting in the grasshopper, *Melanoplus differentialis*. *Proc. Soc. exp. Biol. Med.* 34: 885, 1936 b.

——. The hormonal function of the corpora allata in the grasshopper, *Melanoplus differentialis*. *Anat. Rec.* 70, *Suppl.*, p. 80, 1937 b.

Wheeler, W. M. Hydrocyanic acid secreted by *Polydesmus virginiensis*. *Psyche* 5: 442, 190.

Wigglesworth, V. B. Digestion in the cockroach. I. The hydrogen ion concentration in the alimentary canal. *Biochem. J.* 21: 791, 1927.

——. Digestion in the tsetse fly: a study of structure and function. *Parasitol.* 21: 288, 1929.

——. Some notes on the physiology of insects related to human disease. *Trans. Roy. Soc. Trop. Med. Hygiene* 23: 553, 1930.

——. Digestion in *Chrysops silacea* (Diptera, Tabanidae). *Parasitol.* 23: 73, 1931.

——. The physiology of the cuticle and of ecdysis in *Rhodnius prolixus* with special reference to the function of the oenocytes and of the dermal glands. *Quart. J. Micr. Sci.* 76: 270, 1933.

——. Insect Physiology. *London*, 134 pp. 1934.

——. The physiology of ecdysis in *Rhodnius prolixus*. II. Factors controlling molting and metamorphosis. *Quart. J. Micr. Sci.* 77: 191, 1934 a.

——. Factors controlling moulting and metamorphosis. *Nature, Lond.* 133: 725, 1934 b.

——. Functions of the corpus allatum of insects. *Ibid.* 136: 338, 1935.

Wilson, W. H. On the venom of scorpions. *Rec. Egyptian Gov't. School of Med., Cairo.* 2: 7, 1904.

Yonge, C. M. The function of the tegumental glands in the statocyst of *Homarus vulgaris*. *J. Mar. Biol. Assoc.* 20: 333, 1935 a.

——. Origin and nature of the egg case in the Crustacea. *Nature*, Lond. 136: 67, 1935 b.

——. Evolution and adaptation in the digestive system of the Metazoa. *Biol. Rev.* 12: 87, 1937.

——. 1937 a. The nature and significance of the membranes surrounding the developing eggs of *Homarus vulgaris* and other Decapoda. *Proc. zool. Soc. Lond.* 107A: 499.

Yorke, W., and J. W. S. MacFie. The action of the salivary secretion of mosquitoes and of *Glossina tachinoides* on human blood. *Ann. Trop. Med. Parasitol.* 18: 103, 1924.

Zarin (Sarin), E. Einflues organischer Säuren auf die Bildung und Reifung des Honigs. *Acta Universitatis Latviensis* I, 1917.

STUDIES ON THE EVOLUTION OF SOME DISEASE-PRODUCING ORGANISMS

By CLAY G. HUFF

Department of Bacteriology and Parasitology, University of Chicago

INTRODUCTION

MAN has been able to unravel the evolutionary history of many of the plants and animals which have left fossil records in spite of the tremendous difficulties of the task. He has not met the same degree of success in tracing the origins and evolutionary histories of the disease-producing organisms. Not only did most of these organisms fail to leave any fossil records, but even if they had left good fossil specimens the latter would probably serve us only in a very limited way in making the type of comparison in structure which has been possible in the more complicated animals and plants. In size and external appearance many of the disease-producing organisms are remarkably similar today, even though we can subject them to staining and careful microscopic study. It, therefore, seems very unlikely that the study of fossils will ever have more than a very limited value in uncovering to us knowledge of the early history of these forms. In fact, we have to face the possibility that this early history will forever be obscure to us. The records of the fossils have been and will continue to be helpful in connecting our present knowledge of the organisms, or more particularly of the effects produced by them, with the comparatively recent progenitors of these organisms. It would seem, however, that we shall have to turn to other sources for our ideas about the more remote stories of their past. We have but one choice in this matter. We must seek for this knowledge in the study of living forms. The study of parallel evolution of hosts and parasites has already been an effective tool in clarifying the evolution of both parasite and host when used by such investigators as Kellogg (1913), Metcalf (1923) and Darling (1920). I propose here to use this method to the limited extent possible with our present knowledge in attempting to reveal some of the evolutionary histories of certain disease-producing organisms which are transmitted by arthropods. I am particularly interested in attempting to apply the method to forms having obligate heteroxenous life-cycles. The origin of parasitism in these forms which no longer have any free-living stages presents a particularly fascinating problem. The purpose of this discussion is not so much the presentation of convincing proof of the evolution of these parasitic forms as it is to direct attention to the possibilities of this method in developing this field. The few facts which we now have which may be used in the development of any theory of evolution have resulted from investigations motivated by other desires. It seems only reasonable to suppose that when the desire for adding to our stock of knowledge on the evolution of these forms becomes strong enough, the facts bearing upon this field will be sys-

tematically sought instead of being picked up by the wayside as at present.

In approaching the evolution of the organisms concerned in the production of disease in man and the higher animals, we first face the problem of examining the history of these organisms immediately before becoming human parasites. This question is easily answered in the case of many diseases. We know, for example, that bubonic plague is a disease of rodents which is only incidentally transmitted to man. Undulant fever is a human disease because of the habit of drinking cow's milk. Trichinosis becomes a human parasite whenever man ingests insufficiently cooked pork which is infected with *trichina*. Balantidiosis becomes a serious human disease when the parasite, which ordinarily lives in pigs and apparently produces no ill effects upon the pigs, gains entrance by contamination to the human alimentary tract. The list of such diseases could be greatly extended. They are listed here only as examples of organisms ordinarily affecting other animals which produce disease under special circumstances when introduced into the human body. Such examples serve, however, only to push the problem back one more step. We immediately then face the similar problem of determining where these organisms were before they were parasites of the animal mentioned.

Undoubtedly the disease-producing organisms had very diverse origins. Some could conceivably have been parasitic from the beginning of their existence since certain cells of an animal might have broken loose and assumed an independent existence. They would then have evolved along with their hosts, either changing hosts several times during their evolution or becoming so well adapted to transmission to the progeny of the host that they remained restricted to a given species, or to the species evolving from it. Others were free-living at first and then became adapted to life in one or more types of host. Such parasites as the hookworms show in their life-cycles now the evidence of such a transition, for during the early part of the life-cycle the hookworms are similar in habit to free-living nematodes. In many cases there is insufficient evidence at present to decide what was the probable course of evolution. For example, I should be reluctant at the present time to venture a guess as to whether *Pasteurella pestis* developed first as a parasite of fleas and then of rodents or whether the reverse happened. I intend to discuss only such groups of parasites as seem to me to show good evidence of their origins. My chief interest lies in the group of diseases which are borne by arthropods. Consequently I shall discuss only some of the arthropod-borne infectious agents. I do not wish to be misunderstood as hypothecating that all parasites of man and higher animals had arthropod origins.

ORIGIN OF RICKETTSIAE

The rickettsiae cause diseases of man, such as typhus fever, trench fever, Tsutsugamushi disease, Rocky Mountain spotted fever and the closely related diseases such as *Fièvre Boutonneuse*, São Paulo fever, Eastern spotted fever, and diseases of animals such as heartwater of sheep. The causative organisms of diseases of this kind are all known to be transmitted by arthropods, and the evidence in relation to their evolution is such as to seem incontrovertibly in favor of the belief that they are primarily parasites of arthropods and secondarily of vertebrates. Not only are all of the rickettsiae of vertebrates known to parasitize arthropods also, but a great many similar forms occur in other arthropods and are apparently not parasitic in higher animals. (See Cowdry, 1923,

and Hertig and Wolbach, 1924.) Furthermore, most of them are so well adapted to their arthropod hosts that they no longer produce disease in the arthropod. This close adaptation is also shown in their ability to pass from the infected female arthropod into the egg and thus to the next generation of arthropods. *Rickettsia prowazeki*, which produces typhus fever in man, is exceptional in that it does bring about destruction of the tissues of the louse by which it is transmitted, and also by the fact that it does not pass into the egg of the louse and hence is not hereditarily (congenitally) transmitted to the next generation of lice. Both of these exceptions point toward the relatively recent parasitism of lice by this organism. In fact, there is much reason for believing that in common with other rickettsiae the causative organisms of typhus are of acarinid origin and that they have been lately and poorly adapted to parasitism of body lice of man. Our knowledge of the murine or endemic type of this disease helps to complete the story of its probable origin. This is a rodent disease transmitted by means of rat fleas and rat mites from rat to rat and occasionally from rat to man. Dove and Shelmire (1931 and 1932) demonstrated that this rickettsia can pass through the egg of the rat mite, *Liponyssus bacoti*, and infect the next generation of mites. The most logical hypothesis concerning the evolution of these rickettsiae would seem to me to be as follows. The rickettsiae were associated with mites for long periods of geological time; perhaps even back to a time before the mites had taken up the parasitic habit, and during this time they and the mites became so well adjusted to each other that hereditary transmission was established and the rickettsiae ceased to produce disease in the mites. When the mites became parasitic upon rodents the rickettsiae then occasionally parasitized the rodents and at first probably caused serious disease. There may have been a long period then during which the rickettsiae and rodents became better adapted to each other, but during this time the method of hereditary transmission was retained in the mite and still persists today. After this typhus-like disease was established in rats, the rickettsiae were then taken up by other blood-sucking parasites of the rats and, at least in the case of rat fleas, became well enough adjusted to their new hosts to be transmitted by them (Dyer, Cedar, Rumreich and Badger, 1931). The association with rat fleas has not been long enough, however, to permit the development of the hereditary transmission of the rickettsiae through the eggs of the fleas.

Louse-borne typhus of man most probably originated from the murine type. The latter was occasionally transmitted to man—as it still is today—by rat mites and rat fleas. The adaptation to *Pediculus humanus*, the human body louse, then began and has progressed to the point that typhus can now be carried on in epidemic form by the lice. The rickettsiae are still pathogenic for the louse and have not yet established the hereditary type of transmission. The high pathogenicity for man also indicates that the disease has only recently become a human disease. The term, recently, however, must be interpreted in a geological, relative sense. Zinsser (1935) has clearly shown that the disease is probably very ancient in man in a historical sense.

Trench fever, which is also caused by a rickettsia, may have had an evolutionary history similar to that of typhus, but with a longer association with man as well as with human lice. The lower degree of pathogenicity for each of these hosts would favor this hypothesis. On

the other hand, the rickettsiae which produce trench fever may have been parasites of lice originally and hence not closely related to the rickettsiae of typhus and the typhus-like diseases. Tsutsugamushi disease which would seem to be distinct in many characteristics from both typhus and spotted fever is transmitted by *Trombicula akamushi* which is also an acarinid. If we include trench fever in the typhus group on the first hypothesis or exclude it on the second hypothesis, we find that all of the typhus-like diseases of man and also heartwater of sheep are associated with Acarina and most probably were parasites of ticks or mites originally.

ORIGIN OF CERTAIN SPIROCHAETES

Certain spirochaetes which produce disease in man and animals seem also to have originated from ticks, and a study of their evolution offers an interesting parallel to that of the rickettsiae above. The forms to be considered here are the blood spirochaetes belonging to the relapsing fever group, and the avian spirochaetes. Relapsing fever exists in man in two forms, endemic and epidemic, the former being transmitted by ticks of the genus, *Ornithodorus*, and the latter by human body lice. The endemic type is primarily a rodent disease which is transmitted by *Ornithodorus* from rat to rat and occasionally from rat to man. To strengthen the parallel with endemic and epidemic typhus, the spirochaetes are hereditarily transmitted from the infected tick through the eggs to the following generation of ticks, and this transmission can continue for at least three generations of ticks and perhaps indefinitely, without the need for receiving spirochaetes from another rat. (Möllers, 1907.) A similar hereditary transmission does not occur in the louse. Furthermore, the method of transmission by the louse is an inefficient one. Infected lice are incapable of transmitting the disease to man either by their bites or through contamination by their feces. The spirochaetes live in the coelomic fluid and are transferred to man only when the louse is crushed on his skin. This is obviously an inefficient means of transmission and, together with the other evidence, practically proves that the relationship between the spirochaete and louse is more recent than that between spirochaete and tick. The analogy with the rickettsiae is further strengthened by the fact that similar organisms produce disease in fowl and that these spirochaetes are associated with ticks. The ticks belong to the genus *Argas*, which is closely related to *Ornithodorus*. The spirochaetes of fowls have even been experimentally transmitted by *Ornithodorus*. Hereditary transmission of the spirochaetes also occurs in the female *Argas*.

It would seem very likely then that these spirochaetes were parasites of ticks of the family Argasidae before the latter began to parasitize higher animals. Nicolle and Anderson (1927), however, conceive of relapsing fever spirochaetes as being parasites originally of small mammals, then of *Ornithodorus*, of man, and finally of lice. That the louse strains and tick strains of spirochaetes are not so vastly different today is shown by the experiments of Nicolle and Anderson (1926) in which the tick strain was transmitted to monkeys by lice. A word of caution is needed against the possible attempt to assign to all spirochaetes an argasid origin. Other groups of spirochaetes have probably followed diverse courses of evolution.

ORIGIN OF PIROPLASMAS

The blood parasites belonging to the sub-order Piroplasmidea are protozoa

which parasitize the erythrocytes of mammals (during part of their life-cycle, at least) but which do not produce the malarial pigment, haemozoin. Some examples are *Babesia bigemina*, which causes Texas cattle fever, *Babesia motasi*, *B. ovis* and *B. sergenti* of sheep, *B. caballi*, and *B. equi* of equines, *B. canis*, *B. gibsoni* and *B. rossi* of dogs, and *Theileria parva*, which causes East Coast fever in African cattle. A large number of other species occur in these animals as well as other less well known forms in bats, mice, rats, hedgehogs, moles, monkeys, antelopes and goats. The piroplasmas are of interest to us here because they represent a high degree of parasitism in both their vertebrate and invertebrate hosts. In all cases where the transmission is known, Ixodid ticks are involved. And as shown by Smith and Kilborne (1893) for Texas cattle fever in the tick, *Boophilus annulatus*, some of these forms are normally hereditarily transferred to the progeny of the infected female. In view of the wide diversity of vertebrate hosts infected with piroplasmas, and of the fact that Ixodid ticks seem to serve as intermediate hosts for all of them, it would seem highly probable that they were originally parasites of ticks. Christophers (1934) has pointed out that the ungulates and carnivora, which are the animals chiefly parasitized by piroplasmas, have tended to roam the plains and lands remote from water. In these habitats there would be greater chance of their coming in contact with ticks.

We do not yet know enough about the transmission and life-cycles of the parasites of the genera, *Anaplasma*, *Toxoplasma*, *Grahamella*, and *Bartonella*, to be able to do more than guess at their origins.

ORIGIN OF THE HAEMOFLAGELLATES

The parasites referred to as "haemoflagellates" belong to the Family Trypanosomidae. Besides containing the well-known forms producing trypanosomiasis and leishmaniasis in man and animals, this family includes a large number of forms in invertebrates, and one genus (*Phytomonas*) which lives in the latex of certain plants. The belief that most, if not all, of these parasites were originally parasites of invertebrates and particularly of insects is fairly general now among protozoologists. The case has been very clearly presented by Adler (1933).

The close similarity of the haemoflagellates of vertebrates with those of invertebrates is the chief reason for the belief that they had an association with invertebrates first. Among the insects there is a very large number of species of the flagellates living as parasites of the intestinal tract and being transmitted from one individual insect to another by fecal contamination. Many of these are indistinguishable morphologically from the cultural forms of trypanosomes or leishmanias which produce disease in man and animals. The flagellates which develop in *Phlebotomus* flies and certain other insects when these are fed upon patients having Kala Azar are identical in appearance with the members of the genus *Leptomonas* found naturally in a large variety of insects and not known to involve any vertebrate in their life cycles. In addition to this evidence, a fairly large number of the species parasitic in vertebrates are known to be transmitted from vertebrate to vertebrate by insect vectors. For example, African sleeping sickness of man and nagana of animals are transmitted by blood-sucking flies of the genus *Glossina* (tsetse flies); oriental sore is transmitted by *Phlebotomus*, Chagas' disease by reduviid bugs, and the non-pathogenic *Trypanosoma lewisi* of rats by rat-fleas. It is very easy to see how these insects may have transferred their flagellates to the vertebrates which they

attacked, and then to have continued to act as vectors of the parasites or to have dropped out of the life-cycle completely. It is believed that the latter may have happened in the case of *Trypanosoma equiperdum*, which causes a venereal disease of equines. This is the only *Trypanosoma* of vertebrates known to be unassociated with an insect. In this case the parasite became adapted to transmission by contact during coitus and when this adaptation was perfected the need for the original host—perhaps a biting fly—no longer existed.

It might, perhaps, be argued that the diversity of invertebrate hosts for the haemoflagellates of vertebrates is against the belief in the invertebrate origin of these protozoa. The known vectors include: tsetse flies, sand flies, tabanid flies, hippoboscid flies, fleas, bugs, and leeches. However, these parasites are much more adaptable to new environments than are the malarial parasites. This is proved by the ease with which most of them are cultured *in vitro*. Some of them grow and flourish on such media as potato juice, hydrolyzed haemoglobin, and some even grow on 3 per cent inulin. (Cleveland and Collier, 1930). Others are cultivated with difficulty, but it is still true that as a group they do grow *in vitro*, whereas such forms as rickettsiae, malaria, and piroplasmas have not yet been cultivated in the absence of living host cells. It is also true that the diversity of hosts of the haemoflagellates is not so great as it would seem at first when we reflect that all of the above-mentioned vectors are diptera except fleas, bugs, and leeches. Fleas are closely related in their evolution to flies. Of all the haemoflagellates known, the greatest majority of them are associated with diptera. The haemoflagellates of vertebrates may have evolved from two or three original sources,—one dipteran, one from hemiptera and another from leeches.

ORIGIN OF MALARIAL PARASITES

We shall consider under this heading the parasites of the blood belonging to the genera *Plasmodium*, *Haemoproteus*, and *Leucocytozoon*. Species of *Plasmodium* are found in the blood of man, monkeys, bats, birds and lizards and are transmitted by mosquitoes. They are the true malarial parasites, although this is a modified use of the term *malaria*, since it originally applied to the *disease* in man caused by species of *Plasmodium*. The malaria-like organisms belong to the genera *Haemoproteus* and *Leucocytozoon*. Species of the former occur very widely in birds and to a less extent in reptiles,—both turtles and snakes. Species of the latter are restricted to birds. Species of parasitic flies of the family Hippoboscidae are known to transmit *Haemoproteus* of birds. The vectors of reptilian species of *Haemoproteus* are unknown. Two species of *Leucocytozoon* are now known to be transmitted by blackflies or Simuliidae. (See O'Roke, 1930, and Skidmore, 1932.) The differences between these genera are not as marked or distinct as would seem upon superficial examination. They are generally considered to constitute two families, the Plasmodidae and the Haemoproteidae. The Plasmodidae contains the single genus, *Plasmodium*, and the Haemoproteidae the genera, *Haemoproteus* and *Leucocytozoon*. The distinction between the two families is usually stated to be that the asexual cycle occurs in the circulating blood in the case of the Plasmodidae, while this cycle occurs in "endothelial cells" in the case of the Haemoproteidae. We now know from the work of Huff and Bloom (1935) that in *Plasmodium elongatum* the asexual cycle may and does take place in cells other than circulating red

cells. James and Tate (1937) have also shown that the asexual stages of *Plasmodium gallinaceum* of the domestic fowl are definitely in cells of the spleen and other organs. It, therefore, seems probable that poor criteria have been used in setting up the two families, although it is likely that such natural groups do exist and that other criteria may eventually confirm the original separation. For example, the type of insect vector may prove to be a more valid criterion for separation of genera or families than the types of cells of the vertebrate invaded by the asexual stages. Since in all three of these genera the asexual cycle occurs in the vertebrate and the most of the sexual cycle in insects of the order Diptera, with no free-living stages in the life-cycles, the evolution of these forms assumes great interest and importance in the general problem under discussion.

One obviously has the choice of one of two main hypotheses in attempting to explain how the present state of complete, obligate parasitism may have arisen in this group. We may think of the parasites as having first become adapted to parasitism of vertebrates and then secondarily to the blood-sucking insects which ingested them along with the blood meal. The other possibility is to think of them as being parasites of insects first, probably before the latter had acquired the blood-sucking habit, and then as being transferred to vertebrates after the insect hosts became parasitic on vertebrates. There have been proponents of each of these hypotheses. Therefore, it is not with the claim to authorship of either of them that my views are given here, but rather with the desire of presenting evidence which seems very suggestive, if not conclusive, of the arthropod origin of the malarial parasites.

Regardless of the choice of one of these hypotheses, it would seem logical to assume that there ought to be today more of a parallelism between the parasites and the original group of hosts than between the parasites and the more recent hosts. In the case of such highly developed parasitism as the malarial parasites show, one must assume that the relationship between parasite and host is a very old one. We should, therefore, expect that the evolution of parasites and hosts should have paralleled each other. Likewise, we should expect a better adaptation to exist at present between the parasites and their first hosts than between them and their more recent hosts. This adaptation would result from the processes of natural selection, since the strains of parasites having the greatest pathogenicity for the host would be the most likely to be lost through the death of the host. Likewise the more susceptible of the hosts would be weeded out because of their greater likelihood of succumbing to the effects of the parasite. This type of evidence points in the direction of the insect origin of the malarial parasites.

Let us first consider the natural relationships of the two types of hosts—vertebrate and invertebrate. In the vertebrate hosts we find species of *Plasmodium* resembling each other very closely which parasitize man, monkeys, bats, birds, and lizards. If these parasites had followed the vertebrate hosts in their evolution it ought to follow that in the time it has required for the development of such divergent groups of vertebrates from common precursors the parasites should have changed enough that they would still not be placed in the same genus today. Likewise, there are closely similar species of *Haemoproteus* in present day birds and reptiles. One cannot retreat to the argument that parasites confined to the red cells of these animals would be protected

from the mechanisms of evolutionary change, since we know that the red cells of these various hosts are now widely different chemically and immunologically. The proponents of the theory of the origin of malarial parasites as occuring primarily in vertebrates, point to the close similarity of these forms to the intestinal coccidia. They believe that certain intestinal coccidia developed the ability to live in the blood and then lost the capacity for producing resistant oocysts and passing directly from vertebrate to vertebrate. There is little good evidence for or against such a theory. Such a transfer is known to occur in parasites of the family Lankesterellidae, sub-order Eimeriidea. The coccidian parasite, *Schellackia bolivari*, is found in the intestinal epithelium of the lizards, *Acanthodactylus vulgaris* and *Psammodromus hispanicus*, where it undergoes schizogony. There is a migration of the merozoites destined to produce gametocytes into the subepithelial connective tissue. Here the oocyst is formed and when it bursts, the liberated sporozoites enter erythrocytes and are taken up by the mite, *Liponyssus saurarum*. When the mite is eaten by the lizard, the sporozoites are liberated and they again enter the epithelial cells of the gut of the lizard. The adaptation is carried further in the genus *Lankesterella*. *L. minima* undergoes its complete development in the endothelial cells of the blood vessels of the frog and the sporozoites enter erythrocytes. They are then taken up and transmitted by a leech to other frogs. This is very suggestive of, but it cannot be taken as evidence in favor of, a similar happening in the Haemosporidiidea. In none of the species of the latter is there any evidence that epithelial cells are invaded. On the contrary, *Plasmodium elongatum*, which is not restricted to erythrocytes, lives in a large variety of host cells but these cells are all either blood cells or blood-forming cells (Huff and Bloom, 1935). The epithelial cells are not invaded.

The natural relationships of the invertebrate hosts of the Haemosporidiidea are closely parallel to those of the parasites themselves. Transmission of species of *Plasmodium* is by means of Culicidae or mosquitoes. Furthermore the species of *Plasmodium* in Primates are transmitted by mosquitoes of the tribe Anophelini, whereas those of birds are transmitted by species of the tribe Culicini. In other words, here is just the type of parallelism one would expect if the malarial parasites were primarily parasites of mosquitoes. In further support of this belief, the parasites are known to produce disease in the vertebrate hosts in many instances. Whereas it has been claimed that the parasites have some harmful effect on the mosquitoes, I have been unable to demonstrate any evidence in favor of it in my experiments with avian malaria and *Culex* mosquitoes. The stomach infections in much of my research have been massive. Yet when the infected and uninfected individuals were separately tabulated from the results of several years of research I failed to find any significant differences between the two groups in relation to (a) ability to lay viable eggs, (b) length of life following infective blood meal, (c) length of time between blood meal and oviposition, and (d) number of eggs laid following the blood meal.

Christophers (1934) supports the hypothesis of the insect origin of malaria on basis of the fact that the hosts of *Plasmodium*, birds, bats, and monkeys, live in trees where mosquitoes are more likely to bite them. He would also, in his study of the parasites of monkeys, apes, and man, interpret the absence of crescent forms in monkeys and their presence in

the great apes and man as giving support to the view that the latter constitute independent evolutionary stems, and he sees this possibility as suggesting Africa as the original home of malaria. In my opinion the absence of crescent forms in monkeys is, in addition to being negative evidence, not an important fact if we accept the mosquito origin of malaria. Both crescent and round gametocytes are found also in birds, and the crescent forms occur in reptiles. Therefore, I would think of this difference in fundamental type of gametocyte as having developed very early in the evolution of malarial parasites. It, perhaps, existed in the parasites of the common precursors of the anopheline and culicine mosquitoes. In that case, when mosquitoes began sucking blood from birds and mammals they passed on to both types of hosts species of malaria-like organisms already differentiated in the direction of producing different types of gametocytes. The transmission of the reptilian and chiropteran species of *Plasmodium* has not been worked out in any case as yet. It is a very important point to be determined in the establishment of this theory.

The known vectors of *Haemoproteus* are all Diptera Pupipara which are only distantly related to mosquitoes, but of course, these two groups belong to the same order and hence are more closely related to each other than the vertebrate hosts, birds and mammals. If the hypothesis of the insect origin of the malarias is valid, the vectors of the reptilian species of *Haemoproteus* should be sought for among the cyclorrhaphous blood-sucking Diptera.

The known vectors of *Leucocytozoon* are flies of the family Simuliidae. In this case, however, the vectors are more closely related to mosquitoes than to the hippoboscid flies which transmit *Haemoproteus*, whereas *Leucocytozoon* has been thought to be more closely related to *Haemoproteus* than to *Plasmodium*. However, this latter relationship is somewhat questionable and it may be that when the life-cycles of *Leucocytozoon* are better known they will be found to be closer to *Plasmodium* than has been supposed.

Some very interesting conclusions would follow upon the assumption that all malarial parasites were originally parasites of Diptera and were secondarily adapted to living in vertebrates. Since present day life-cycles of all of them involve schizogonous cycles in the vertebrate hosts it might be assumed that this is a later outgrowth from life within the vertebrate. In other words, the schizogonous cycle may have been intercalated into a like cycle essentially like that of the gregarines. Another interesting outgrowth of this assumption might occur. Since the life cycles of all three of the genera, *Plasmodium*, *Haemoproteus*, and *Leucocytozoon*, are practically identical in detail within their respective hosts, mosquitoes, hippoboscid flies, and blackflies, and since these diptera probably first transmitted the parasites to vertebrates through their bites, it would seem probable that the original cycle in the diptera involved passing the infective stage of the parasite through the mouthparts. This infective stage would have had to be a resistant stage which could live for a short time in the environment until it could be acquired by another similar fly. Another possible hypothesis would be that this infective stage was injected into and lived in plants before the insects acquired the blood-sucking habit. This would be in agreement with the general belief that the blood-sucking habit in insects arose from forms which were adapted to sucking plant juices. Another conclusion which would

result from the proof of these hypotheses is that although the stages of malarial parasites and piroplasmas which live in erythrocytes often resemble each other very closely, this similarity may have developed recently because of long residence in similar environments. Actually the two groups would appear on this hypothesis to have had widely divergent courses of evolution.

It is unfortunate that fossil records are too inadequate to give us any positive evidence for or against this theory. However the following statement about the geological history of the Culicidae by Edwards (1932) is of interest in this connection:

> Since we have reason for believing that the order Diptera arose not later than the Triassic Period, and since the *Culicidae* are certainly one of the more primitive families of the order, it is highly probable that members of this family existed during the Jurassic period, before the age of mammals; the fact that many *Culex* at the present day attack lizards and frogs suggests that even the blood-sucking habit may have been developed at this early period. Unfortunately the known insect-bearing beds of Jurassic or Cretaceous age are few, and in them no remains of *Culicidae* have yet been found. We have therefore no direct palaeontological evidence as to the time of origin or phylogenetic history of the family. In the Oligocene rocks of the Isle of Wight and Germany remains of *Culicidae* are numerous, but the species hardly differ from those of the present day; all the three subfamilies are represented, as well as the genera *Dixa*, *Chaoborus*, *Mochlonyx*, *Culex*, *Aëdes* and perhaps *Theobaldia*, *Mansonia* and *Megarhinus*. Our knowledge of fossil *Culicidae* was reviewed by the writer in 1923 (Quart. Journ. Geol. Soc., 79, p. 139, 155)."

There remains one point to be stressed. If we assume for the moment that the theory that malarial organisms began their parasitic existence in vertebrates is the correct explanation, we must assume that the ability to transmit these parasites was more or less accidentally acquired by arthropods which took up the habit of sucking blood from these vertebrates. It then becomes difficult to understand why the only successful vectors were diptera. Since such forms as lice, fleas, ticks, and mites have been parasitic much longer than most of the diptera it would seem that some of them had an excellent opportunity to establish a harmonious relationship with the parasites. Yet this does not seem to have happened.

SUMMARY AND CONCLUSIONS

Since little or nothing is known of the early evolutionary development of most of the organisms producing disease and since the possibility of ever securing much information bearing on this question seems remote, an attempt has been made here to approach this question from a study of contemporary parasites and their relations to their hosts. The organisms chosen are all arthropod-borne and belong to the rickettsiae, the spirochaetes, and the protozoa. In general they represent parasitism of a high degree in which there are no longer any free-living stages. The evidence seems to be strongly in favor of the belief that parasitism among these groups began in the invertebrates and was secondarily transferred to vertebrates when the invertebrate hosts became blood-sucking. This seems to hold for the rickettsiae, certain spirochaetes, the piroplasmas, the haemoflagellates, and the malarial organisms. Extension of the theory to include other groups, or generalizing upon the cases here presented should be done with due caution and consideration for the relationships within the other groups. It is hoped that the method employed here will be extended by others to the parasites in which they are most interested. The problem would seem to be important enough to warrant the collection of facts and the planning of experiments to clarify some of the points now poorly understood.

LIST OF LITERATURE

ADLER, S. 1933. Mode de transmission des protozoaires sanguicoles et particulièrement des leishmanioses. *Bull. d. l. Soc. path. exot.* 26: 207–222.

CHRISTOPHERS, R. 1934. Malaria from a zoological point of view. *Proc. Royal Soc. Med.* 27: 991–1000.

CLEVELAND, L. R., and COLLIER, J. 1930. The cultivation and differentiation of haemoflagellates in autoclaved media. *Amer. Jour. Hyg.* 12: 614–623.

COWDRY, E. V. 1923. The distribution of rickettsia in the tissues of insects and arachnids. *Jour. Exper. Med.* 37: 431.

DARLING, S. T. 1920. Observations on the geographical and ethnological distribution of hookworms. *Parasitology.* 12: 217–233.

DOVE, W. E. and SHELMIRE, B. 1931. Tropical rat mites, *Liponyssus bacoti* Hirst, vectors of endemic typhus. *Jour. Amer. Med. Assoc.* 97: 1506–1510.

——. 1932. Some observations on tropical rat mites and endemic typhus. *Jour. Parasit.* 18: 159–168.

DYER, R. E., CEDAR, E. T., RUMREICH, A., and BADGER, L. F. 1931. Typhus fever; the rat flea, *Xenopsylla cheopsis* in experimental transmission. *U. S. Pub. Health Rept.* 46: 1869–1870.

EDWARDS, F. W. 1932. Diptera. Culicidae. In *Wytsman's Genera Insectorum* (see pp. 6–7).

HERTIG, M., and WOLBACH, S. B. 1924. Studies on rickettsia-like micro-organisms in insects. *Jour. Med. Res.* 44: 329–374.

HUFF, C. G., and BLOOM, WM. 1935. A malarial parasite infecting all blood and blood-forming cells of birds. *Jour. Infect. Dis.* 57: 315–336.

JAMES, S. P., and TATE, P. 1937. New knowledge of the life-cycle of malaria parasites. *Nature.* 139: 545.

KELLOGG, V. 1913. Distribution and species-forming of ecto-parasites. *Amer. Naturalist.* 47: 129–158.

METCALF, M. M. 1923. The opalinid ciliate infusorians. *U. S. Nat. Mus. Bull.* 120: 1–484.

MÖLLERS, B. 1907. Experimentelle Studien über die Übertragung des Rückfallfiebers durch Zecken. *Zeit. f. Hyg. u. Infekt.-Krankh.* 58: 277–285.

NICOLLE, C., and ANDERSON, C. 1926. Fièvre récurrente; transmise à la fois par Ornithodores et par poux. Étude expérimentale de la récurrente espagnole. *Arch. de l'Inst. Past. de Tunis.* 15: 197–228.

——. 1927. Sur l'origine des fièvres récurrentes humaines. *Bull. de l'Inst. Past.* 25: 657–665.

O'ROKE, E. C. 1930. The incidence, pathogenicity, and transmission of *Leucocytozoon anatis* of ducks. *Jour. Parasit.* 17: 112. (abs.)

SKIDMORE, L. V. 1932. *Leucocytozoon smithi* infection in turkeys and its transmission by *Simulium occidentale* Townsend. *Zent. f. Bakt., Parasit. u. Infekt.* 125: 329–335.

SMITH, T., and KILBORNE, F. L. 1893. Investigation into the nature, causation and prevention of Texas or Southern cattle fever. *U. S. Dept. Agric. Bur. Anim. Indust.* 1: 177–304.

ZINSSER, H. 1935. Rats, Lice and History. ix + 301 pp. Boston.

THE PUBLISHING BEHAVIOR OF BIOLOGISTS

By JEAN DUFRENOY

Station Pathologie Vegetale, Bordeaux, France

I

THE index of the *Review of Applied Mycology* for 1935 lists 1085 authors (including joint authors) who published one paper dealing with plant pathology; 285, 95, 31, 24, 5, 3, 1. Other authors published respectively 2, 3, 4, 5, 6, 7 or 8 papers.

For that year (1935) the observed frequencies (o) of authors communicating 1, 3, 4 papers do not deviate significantly from the frequencies calculated (c) by assuming that the frequency for one paper being $(3.20)^6$, that for 2, 3, 4, 5 is respectively $(3.20)^5$, $(3.20)^4$, $(3.20)^3$, $(3.20)^2$, 3.20 (Table 1 and Graph 1).

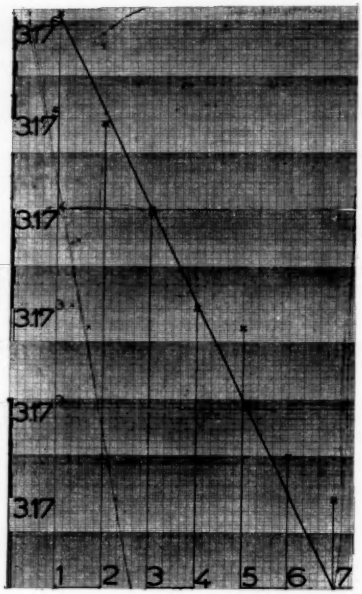
In other words, the assumption is that the probability for an author to publish one paper being p_1, that to publish 2, 3, 4, 5 is respectively $(p_1)^2$, $(p_1)^3$, $(p_1)^4$, $(p_1)^5$ which is one example of application of the general law of compound probability.

The observed frequencies for two papers are consistently significantly lower than

TABLE 1

Frequencies (o) of authors having 1, 2..... 7 papers abstracted in the Review of Applied Mycology

Year	x	o	c	$(o-c)$	$(o-c)^2$	$\frac{(o-c)^2}{c}$
1932	1	951	887	64	4096	4.6
	2	224	286	62	3844	13
	3	82	92	10	100	1
	4	27	29.8	2.8	7.8	0.27
	5	22	9.6	12.4	153	16
	6	13	3.1	9.9	—	—
						34.87
1934	1	1032	1033.6	1.60	2.56	0.0002
	2	244	325.18	81.	6561	20
	3	101	102.26	2.26	5	0.05
	4	31	32.15	1.15	1.32	0.04
	5	17	10.11	7	49	4.90
	6	8	3.18	4.8	23.	7
						31.99
1935	1	1085 $(3.20)^6$	1073.7	13.3	177	0.165
	2	285 $(3.20)^5$	335.5	50.5	2550	7.40
	3	96 $(3.20)^4$	104.86	8.86	77.44	0.73
	4	31 $(3.20)^3$	32.77	1.7	12.90	0.10
	5	21 $(3.20)^2$	10.24	10.8	116	11.37
	6	5 (3.20)	3.20	1.8	3.24	1
						20.76



GRAPH 1. THE LOG OF CALCULATED FREQUENCIES OF AUTHORS, $3.1F^{(y-x)}$ ARE PLOTTED AGAINST THE NUMBER (x) OF PAPERS PUBLISHED IN THE YEAR, RESULTING IN A STRAIGHT LINE; THE OBSERVED FREQUENCIES y FOR $x = 1, 2, 3, 4$ PAPERS DO NOT DEVIATE SIGNIFICANTLY FROM THE STRAIGHT LINE

the calculated frequencies, while the observed frequencies for more than four papers are markedly in excess, suggesting that authors who contribute two and those who publish more than four papers constitute a group which does not belong to the same series with authors contributing one, three or four papers.

TABLE 2

Frequencies (o) of authors contributing 1, 2, 3, 4 papers to vol. 120 of Comptes rendus Société de Biologie

$$\frac{o_x}{o_x + 1} = n = 4.25$$

x	o	c	$o - c$	$(o-c)^2$	$\frac{(o-c)^2}{c}$
1	330	326.26	3.75	14	0.04
2	69	76.76	7.76	60	0.80
3	14	18.06	4.06	16	0.80
4	5	4.25	1.75	3	0.70
					$2.34 = \chi^2$

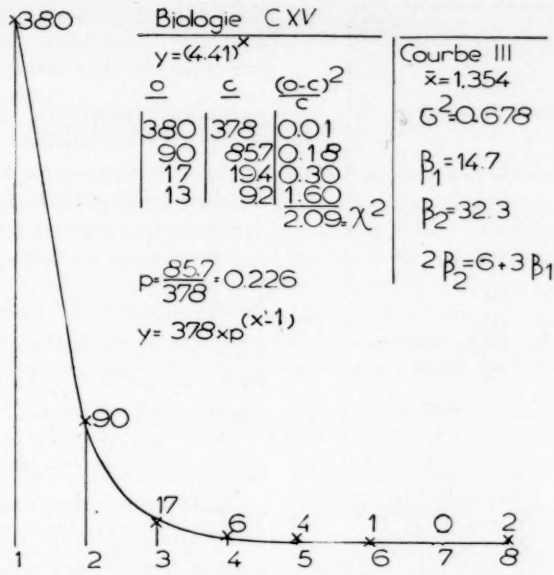
For the three years 1935, 1934, 1932, the observed frequencies for 1, 3, 4 papers do not differ significantly from the calculated frequencies, χ^2 being less than 5.99 which is the χ^2 value for $P = 0.05$ for 2 degrees of freedom.

x	1932	1934	1935	χ^2
1	4.6	0.0002	0.165	4.8
2	13.	20.	7.40	40.40
3	1.	0.05	0.70	1.75
4	0.27	0.04	0.10	0.51
5	16.	4.90	11.3	32.

TABLE 3

Frequencies (o) of authors having had $x = 1$, $x = 2$.....$x = 5$ notes printed in the Comptes rendus Société de Biologie, v. 115, or v. 118, during the period of January–April 1934 or 1935, respectively

	VOL. 115			VOL. 118		
x	o	c	$\frac{(o-c)^2}{c}$	o	c	$\frac{(o-c)^2}{c}$
1	380	$4 \cdot 4^4 = 372.5$	0.15	330	$4 \cdot 3^4 = 311.2$	0.37
2	90	$4 \cdot 4^3 = 85.2$	0.24	81	$4 \cdot 3^3 = 79.5$	0.026
3	17	$4 \cdot 4^2 = 19.3$	0.27	23	$4 \cdot 3^2 = 18.5$	1.1
4	6	$4 \cdot 4^1 = 4.4$	0.60	2	$4 \cdot 3^1 = 4.3$	1
5	4	$4 \cdot 4^{\frac{1}{2}} = 2.1$	0.70	1	$4 \cdot 3^0 = 1^{5.3}$	
6	1^5	$4 \cdot 4^{\frac{1}{4}} = 1.4^{3.5}$				
7	—					
8	2					
			1.96			2.496
			χ^2			χ^2



GRAPH 2. THE FREQUENCIES OF AUTHORS ARE PLOTTED AS ORDINATES (y) AGAINST THE NUMBER OF PAPERS (x) CONTRIBUTED TO VOL. 115 OF COMPTES RENDUS SOCIÉTÉ DE BIOLOGIE
The distribution can be adjusted to the equation $y = (4.41)^x$, or to a type III Pearson curve assuming the mean number of papers being $\bar{x} = 1.354$.

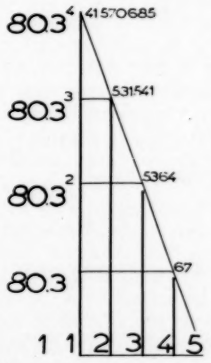
II

The distribution of frequencies of authors (or joint authors) from various parts of the world communicating 1, 2, 3, 4 papers published in vol. 120 of *Comptes rendus de la Société de Biologie* (1935) so approximates the distribution of $(4.25)^x$ that each individual value of χ^2 (for each discrepancy) is very probable, while the 4 values sum up to 2.34 which is very close to 2.36, the most probable value for 3 degrees of freedom. (Table 2.)

Barring the erratic behavior of a few individuals contributing more than 7 papers a year, the distribution of frequencies of authors contributing 1 to 7 papers a year can be adjusted to a simple calculated distribution. (Table 3.)

For two degrees of freedom, the probabilities of $\chi^2 = 1.96$ and $\chi^2 = 2.5$ are about $P = 0.40$ and $P = 0.30$. The calculated frequencies therefore do not differ significantly from the observed.

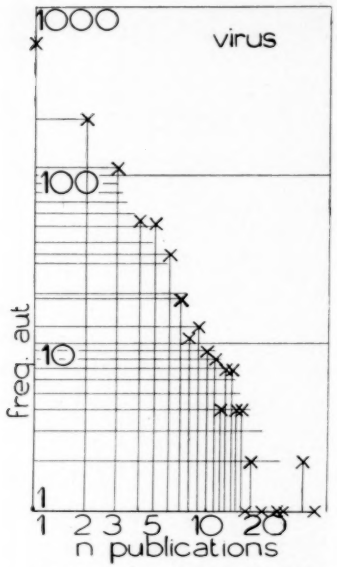
Examples 1 and 2 illustrate the general



GRAPH 3. A TOTAL OF 42,107,657 BIRTHS WERE RECORDED IN GERMANY FOR 1901–1935: THE OBSERVED FREQUENCIES (y^1) OF SINGLE BIRTHS, OF TWINS, TRIPLETS OR QUADRUPLETS ARE LISTED BELOW AND CHECKED AGAINST THE FREQUENCIES CALCULATED FROM $80.3^{(5-x)}$ WHERE x IS THE DEGREE OF MULTIPLE BIRTHS

Degree (x)	*Observed* (y^1)	*Calculated* (y)	
1	41,570,685	41,577,864	$= 80.3^4$
2	531,541	517,781	$= 80.3^3$
3	5,364	6,448	$= 80.3^2$
4	67	80.3	
5	0	1	

On the graph, the log of the frequencies are plotted as ordinates against the "degrees" of multiple births.



GRAPH 4. NUMBER OF AUTHORS (ORDINATES) HAVING HAD 1, 2, ··· *n* PAPERS LISTED IN M. T. COOK'S PARTIAL BIBLIOGRAPHY ON PLANT VIRUSES
(Plotted on log. grid.)

law: if the separate probability of each of *n* several independent events be *p* the probability of all *n* events occurring is p^n.

Again the formula $n^{\frac{1}{x-1}}$ is that presented by German statisticians to express the frequency relation of multiple births; *n* is the ratio of single births to twin births that occur in a given series of birth statistics [in a series quoted by the *Journal of Heredity* (26: 256, 1935), $n = \frac{41,570,685}{531,541}$] while *x* shows the degree of multiple births in question (i.e. twins, triplets, quadruplets). (Graph 3.)

M. T. Cook listed 3214 publications about plant viruses, originating from 1161 authors, 700 of whom contributed 1 paper, 110 contributed 2; the frequencies (*y*) of authors contributing 1, 2, 3, 4, ··· *x* papers can be plotted on a straight line using equation $\log (y) = -k \log (x)$.

NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to Dr. Raymond Pearl, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *1901 East Madison Street, Baltimore, Maryland, U. S. A.*

BRIEF NOTICES

EVOLUTION

GENETICS AND THE ORIGIN OF SPECIES. *By Theodosius Dobzhansky. Columbia University Press, New York.* $3.60. 9 x 6; xvi + 364; 1937.

When Darwin propounded his theory of the origin of species by the natural selection of heritable variations little was known in detail of two of the phenomena on which the theory was based—the origin of new variations and their perpetuation by heredity. Since then the geneticists have added much to our knowledge of these phenomena. For a time, indeed, it seemed that this new knowledge did not contribute much to our understanding of the origin of species. Later developments in genetics, however, have thrown more light on the problem and the purpose of this book is to synthesize this information.

Changes in the chromosomes—mutations of individual genes, rearrangements of the genes within the chromosomes, and reduplications and losses of whole chromosome sets (polyploidy)—furnish the raw materials for evolution. In different environments natural selection will favor different combinations of genes and thus separate what was a continuously varying population into subgroups with discontinuities between them. Besides this effect of selection in producing adaptive discontinuities there is another non-adaptive factor also tending to split a species into subgroups. As Hardy has shown, in a large population unaffected by mutation or selection the relative frequencies of various genes remain constant from one generation to another. In small populations, however, deviations from the expected frequency of a gene occur and once the frequency of a gene reaches zero the gene is irretrievably lost unless it is reintroduced by a new mutation. The effective size of population, moreover, is not the total number of the species but the size of the colony within which interbreeding occurs. Thus in different colonies chance factors will eliminate different genes and produce local races. It is probable that the local races of *Partula* which Crampton found in the different valleys of Moorea and for which he could find no adaptive explanation were produced by this chance mechanism.

The isolation of such local races is, however, not absolute and interbreeding between them would in time break down the discontinuities which separate them. A number of mechanisms prevent such interbreeding. The races may breed at different times. Members of a different race may be less attractive sexually than members of the same race. Finally different mutations and rearrangements of the genes in the different groups may prevent interbreeding or render the offspring sterile. Such isolating mechanisms fix

the diversity which has been produced by mutation, selection and random variation in frequency of genes.

This is a book which will repay careful study by every biologist. It includes a bibliography of 28 pages and an index.

EVOLUTION AND ITS MODERN CRITICS.

By A. Morley Davies. Thomas Murby and Co., London. 7s. 6d. net. $7\frac{3}{8}$ x $4\frac{7}{8}$; xii + 277; 1937.

The original plan was to publish this work primarily as a reply to Mr. Douglas Dewar's "Difficulties of the Evolution Theory" but the book has been expanded beyond that point so as to serve as an expression of the author's own ideas on evolution rather than as a mere rejoinder. After a survey of old and new ideas of evolution, sample families selected from the Mammalia and Mollusca, with detailed discussions of the paleontological records, are introduced to test "evolution within the family but not beyond it." The formidable assortment of facts and pseudo-facts that have been accumulated by a long line of biologists in support of various principles of evolution is subjected to an analysis that is as brilliant as it is comprehensive. There is a glossary, a short bibliography, and an index.

LIFE LONG AGO. *A Story of Fossils.*

By Carroll L. Fenton. Reynal and Hitchcock, New York. $3.50. $9\frac{1}{4}$ x $6\frac{3}{4}$; x + 287 + 14 plates; 1937.

The youngster who has a scientific bent strong enough to keep him from being phased by a whole set of new and usually long words, may derive considerable pleasure and quite likely a zest for some fossil hunting from this story of the fossil remains of prehistoric life. The author takes his young readers with him on imaginary excursions to regions where the now fossilized plant and animal forms once abounded as living things. Here he reconstructs for his audience the story of this long ago existence and shows how, from a study of fossils of different ages, changes in form may be seen taking place. Fourteen plates of photographs and many drawings of fossils and "restorations" are included to illustrate the text.

A CHALLENGE TO EVOLUTIONISTS.

By Douglas Dewar. Thynne and Co., London. 2s. 6d. $7\frac{7}{8}$ x $5\frac{1}{4}$; 63; 1937.

This is a report of Mr. Dewar's remarks on evolution, made during a debate with Mr. Joseph McCabe on February, 1937. Since Mr. McCabe's speeches have not been included, the author regards the volume in the nature of a challenge to evolutionists.

GENETICS

YEARBOOK OF AGRICULTURE, 1937.

U. S. Department of Agriculture. Government Printing Office, Washington. $2.00. 9 x $5\frac{3}{4}$; 1497; 1937.

AGRICULTURAL STATISTICS, 1937.

U. S. Department of Agriculture. Government Printing Office, Washington. 50 cents. $9\frac{1}{4}$ x $5\frac{3}{4}$; 486; 1937 (paper).

The present volume of the yearbook of agriculture brings to completion the reports of a committee which set out in 1933 to make a survey of practical breeding and genetic research with those plants and animals that are of importance in American farming. The report on major crop plants and classes of live stock were published in the 1936 yearbook. The series of papers presented in this number cover a variety of subjects: garden vegetables, northern tree and bush fruits, subtropical fruits, flowers, nut trees, forest trees, forage grasses and legumes, Angora and milk goats, turkeys, ducks, furbearing animals, honeybees, and the dog. The general purpose underlying this survey of breeding and genetics has been an attempt to show the achievements of the past, the situation of the present, and the possibilities of the future. The yearbook is as usual prefaced by the yearly report of the Secretary of Agriculture to the President.

In the 1937 volume of Agricultural Statistics, all of the most important statistical data of the United States, and

of the world so far as they relate to the agriculture of this country, are brought together and presented in some 574 tables. An index makes possible easy reference to all data.

GENERAL BIOLOGY

DESIGN IN NATURE.
By James Ritchie. Charles Scribner's Sons, New York; County Life Limited, London. $2.00. 7¼ x 4⅞; 142 + 29 plates; 1937.

This book might well have been entitled "Rhythms in Nature," because the author has seized every opportunity available to show that all life, whether simple or complex, follows a definite cycle or rhythm in all of its manifestations. Mr. Ritchie has shown that the foremost of all rhythms or cycles in the living world is the energy cycle which includes: (1) the capture of energy from the sun by green plants and the conversion of that energy into a form available to animals; (2) the use of the energy by animals; and (3) the combination of a portion of it with more energy from the sun into more green plants. The cycles of day and night and of winter and summer are so important in their influences that the result is a constantly moving cycle of activity and inactivity among almost all forms of life.

The volume is clearly written in a stimulating style, and is rich in first hand observations drawn from the author's personal experience as a naturalist in the field. It is not difficult for us to understand how a man so intimate with nature as the author could attribute song (frog's, bird's, etc.,) to a sense of well-being in the animal. However, to our knowledge, no scientific proof has yet appeared to show that this is the case, and until it does, it requires a slight stretch of imagination to attribute to either frogs or birds the intelligence required to reason, " 'God's in his heaven; all's right with the world'—I'll sing."

The book is intended not so much for the student of natural history, as for the layman who has an earnest desire to learn more of the intricacies of life about him. In addition to a short table of contents and an index, the text contains a large number of illustrations that would greatly enhance the value of any study in natural history.

GENERAL SCIENCE: BIOLOGY.
By E. R. Spratt and A. V. Spratt. University Tutorial Press, London. 2s. 6d. 7¼ x 4¾; vii + 216; 1937.

A TEXTBOOK OF GENERAL BIOLOGY. *Second Revised Edition.*
By E. Grace White. C. V. Mosby Co., St. Louis. $3.00. 8½ x 5½; 667; 1937.

The first of these books is one of the best elementary books in general biology that we have seen in many a day. It was prepared with the idea of presenting the essentials of biology to those wishing to take various English school certificate, Civil Service or L.C.C. clerkship examinations. The types are well selected and easy to obtain. The diagrammatic method of illustration is largely used and much thought and skill has gone into the preparation of these drawings. Some of the main problems of food and health of the human race are discussed briefly and simply. There is an index.

The second book listed (a college text) has, under the able editorship of its author, maintained the high quality of the first edition (noticed in Q.R.B. Vol. 8, No. 4) As in the earlier issue the assistance of outstanding biologists has been obtained in developing the various sections. In the revision there have been embodied many suggestions of those who have used the book. The subject matter has been rearranged, new material included and the number of illustrations, which are excellent, increased to 336. A glossary and index complete the volume.

ASCARIS: *The Biologist's Story of Life.*
By Richard Goldschmidt. Prentice-Hall, New York. $3.25. 8 x 5½; ix + 390; 1937.

"Man must be taught as if you taught them not . . . ," and in its charmingly conversational style this book written for the layman's biological edification

adheres closely to the 18th century aphorism. The story opens with the roundworm, *Ascaris*, enjoying an exceedingly leisurely parasitic existence in a horse's small intestine. However, he is, in short order, rudely removed by the author from this comfortably alkaline position, killed with ether fumes, and dissected. Using *Ascaris* as a constant focal point, the writer digresses into descriptions of divers animals, their adaptations to the environment, and the interrelations of all life including man. Animal forms, regeneration, transplantation, and inheritance of acquired characters are discussed in the first few chapters; the succeeding chapters likewise touch many fields of physiology, histology, bacteriology, immunology, evolution, and genetics in kaleidoscopic and interesting review. The use of non-scientific language and splendid illustrations serve to make this a charming story of the wonders of the biological world with a roundworm as its hero and the story of his life as a source of all biological revelations.

BIOLOGY FOR MEDICAL STUDENTS. *Second Edition.*

By C. C. Hentschel and W. R. Ivimey Cook. With a Foreword by G. E. Gask. Longmans, Green and Co., New York. $7.50. 8½ x 5½; xii + 664; 1937.

In view of the revised examination syllabuses of several English universities, this text-book has in turn been revised and new material has been added. The first half of the work is devoted to the animal kingdom, the material being presented by the study of a particular form in each of the larger phyla. The vertebrates are treated by classes, including a chapter on embryology.

Dr. Cook's section on the plant kingdom deals primarily with the flowering plant, including anatomy, histology, and physiology. In the remainder of the book plants, animals, and bacteria are considered in their adaptation to the environment—particulary those forms which are parasitic to the human host.

The text is admirably written and organized, but would require accompaniment by an extensive laboratory course to insure clear understanding by the novice. Those of the illustrations which are uncopied are frequently poor in quality. The table of pefixes and suffixes should be of help to the student.

WEATHER. *Natural History Studies.*

By Gayle Pickwell. Hugh F. Newman and Co., Los Angeles. $3.00. 11½ x 9; x + 170; 1937.

There is probably no single factor in man's environment that affects him more than the weather. It affects him not only physiologically but economically and socially as well. And it is impossible to get away from the weather. It may be good or it may be bad, but it is always something. If we accept Huxley's definition of a liberal education we must believe that it is incumbent for anyone who wishes to consider himself liberally educated to acquire at least a rudimentary knowledge of meteorology. Yet the average man's knowledge of meteorology consists of a few superstitions connected with rainbows and groundhogs. To all such people the present work may be most highly recommended. It is an excellent example of modern bookmaking with photographs running to the edges of the page, good paper, and clear type. There are illustrations of thirteen types of clouds, three types of fog, several kinds of lightning, of different kinds of landscapes, with descriptions of the kind of climatic conditions that produce them. There are also descriptions of various kinds of storms, the work of wind and water, and instructions as how to read weather maps.

The book is one of a series of introductory works in natural history, bound together by the photographs, all of them the work of the same author.

THE RÔLE OF CHEMIOTAXIS IN BONE GROWTH.

By A. P. Bertwistle. Henry Kimpton, London. 8s. 6d. net. 9¾ x 6; xii + 59; 1937.

"That bone is the most interesting tissue

in the body is," in the opinion of this author "beyond dispute." The purpose of his book "is to describe Disruptive Chemiotaxis, a new process to medicine; and to lay down a law which, based on histological grounds will be found to cover the whole field of bone pathology, viz.: "*That whenever young fibrous tissue, particularly young blood-vessels, come into contact with bone or a calcified deposit, new bone formation occurs.*" Disruptive chemiotaxis is "the power of certain hard substances of attracting and drawing into themselves certain soft, living structures." One of his prime illustrations of this tropism is that the roots of germinating seeds pierce the hard ground instead of lifting the seed in the air, which does not seem to us to bear much relation to what he later describes as taking place in bone diseases. Most of the text consists of briefly cited examples from pathology to prove this all-inclusive theory.

AN EXPERIMENTAL STUDY OF THE PROBLEM OF MITOGENETIC RADIATION. *Bulletin of the National Research Council, Number 100.*

By Alexander Hollaender and Walter D. Claus. National Research Council, Washington, D. C. $1.00. $9\frac{3}{4}$ x $6\frac{3}{4}$; 96; 1937 (paper).

The purpose of this investigation was to prove or to disprove the existence of the so-called mitogenetic rays. Both biological and physical detectors were used in a series of carefully carried out experiments and in all cases there was no indication that any measurable ultraviolet radiation was given up by typical mitogenetic senders. As a biological sender, colonies of *Escherichia coli* were used, while a Geiger-Müller photon counter was the physical detector.

The problem was further investigated by determining the sensitivity of biological materials to ultraviolet radiation in the range of intensities which approach those reported for mitogenetic rays. Some effects on growth properties of surviving organisms were noted, but the energies needed to produce these effects were outside the limits of the energies reported for mitogenetic radiation.

THE PHYSICAL BASIS OF GEOGRAPHY. *An Outline of Geomorphology.*

By S. W. Wooldridge and R. S. Morgan. Longmans, Green and Co., New York. $4.80. $8\frac{1}{2}$ x $5\frac{1}{2}$; xxi + 445; 1937.

In the first 10 chapters of this textbook the authors present an outline of geophysics and structural geology including considerations of the facts and theories regarding the origin of the earth, the constitution of its interior, isostasy, the nature and origin of earth-movements, the building of mountains, vulcanicity and formation of rocks. In the final 13 chapters, landforms due to erosion are discussed at length. In the exposition of the subjects treated in these chapters the authors follow the methods and ideas laid down by Davis. While this is primarily a textbook for students of geography it is written in such an interesting fashion that it should find favor with ecologists generally. The photographs and illustrations are clear and helpful.

THIS IS OUR WORLD.

By Paul B. Sears. University of Oklahoma Press, Norman. $2.50. $7\frac{3}{4}$ x $5\frac{1}{4}$; xi + 292; 1937.

Books written for noble and admittedly worthy puposes are highly irritating to most of us. Even our most righteous citizens find that once a week is enough for sermons. We are therefore pleased to report that straight through to page 233 this treatise on soil and water conservation is most agreeable and interesting reading. Mr. Sear's literary style, buttressed by comic cartoons, is such as to coax rather than bully us into agreeing with him. But then, having won his point, he proceeds to tack on an irrelevant section about sociology and ends with a Fourth of July political speech which succeeds in taking all the healthy sting from what he has previously said.

LA VIE CELLULAIRE HORS DE L'ORGANISME. *La Culture des Tissus.*

By Jean Verne. G. Doin and Cie, Paris. 38 francs. $8\frac{5}{8}$ x 6; x + 192; 1937 (paper).

The author has not attempted to write a complete treatise on tissue culture, but has selected interesting aspects of the subject for brief discussions. Cells *in vitro* possess a morphology and a physiology that contribute important data to biological problems, and have led to significant results. Removing cells from the influence of the organism discloses potentialities which otherwise do not usually appear. This permits new approaches to the study of normal and pathological reactions and it is this aspect of the subject that the author dwells on.

AIDS TO THE STUDENT OF CONSERVATION. *Review and thought-provoking questions concerning Our Natural Resources and Their Conservation. Edited by Parkins and Whitaker.*

By Stephen S. Visher. John Wiley and Sons, New York; Chapman and Hall, London. 25 cents. 10¾ x 8¼; 32; 1937 (paper).

This pamphlet was prepared to accompany Parkins' and Whitaker's *Our Natural Resources and Their Conservation* which was published in October 1936. For each of the twenty-three chapters of the original, Dr. Visher has supplied a page of "review" and "thought-provoking" questions. Spaces for brief written answers are provided for many of the questions and the pages are perforated so that the separate tests may be easily torn out and handed in to the instructor.

HUMAN BIOLOGY

COLLECTED STUDIES ON THE DIONNE QUINTUPLETS. *St. George's School for Child Study, The University of Toronto.*

By W. E. Blatz, M. Chant, M. W. Charles, M. I. Fletcher, N. H. C. Ford, A. L. Harris, J. W. MacArthur, M. Mason and D. A. Millichamp. University of Toronto Press, Toronto. $4.00. 9 x 6; [8] + 206 + 39 plates + 13 tables + 9 charts + 5 folding charts; 1937.

This book consists of six different papers reporting investigations carried out on the Dionne quintuplets under the direction of St. George's School for Child Study of the University of Toronto.

In the first paper J. W. MacArthur and N. H. C. Ford discuss the evidence for monozygosity in these siblings. On the basis of the nature of the fetal membranes, the close resemblance of the quintuplets in a great number of hereditary characters, and the youth of the mother coupled with the absence of any inherited proclivity to production of twins in the immediate family they conclude that the set is derived from a single ovum. The medical literature on quintuplet births is discussed and a pertinent bibliography appended. Eight plates are presented, including finger, palm and sole prints of all the children, and right and left profile and full face views.

The second paper by W. E. Blatz and D. A. Millichamp presents the results of mental tests begun in the 11th month of life and continued at intervals of two months. Three test forms were used, the Gesell, the Kuhlman and the Merrill-Palmer (Stutsman). The actual test results are shown in an appendix. The apparent retardation of these five children is attributed primarily to their prematurity, with two other factors difficult of evaluation, environmental arrangements and inheritance, postulated as contributory.

The third paper on the early development of the quintuplets, by W. E. Blatz, D. A. Millichamp, and M. W. Charles presents an analysis of observations from the 12th to the 36th month. Records were made of the social contacts of each child with the other four. The results are presented in detail in eight tables and 7 charts. The conclusion is reached that "these five children already manifest quantitative and qualitative social and personality differences of a more or less stable nature."

The fourth paper by W. E. Blatz, D. A. Millichamp, and N. Chant, presents data pointing to the conclusion that the five children show marked individual differences in their emotional background and in their attitudes towards authority. It is suggested that "however one defines personality the chief influences towards

its development are environmental rather than hereditary."

The fifth paper by W. E. Blatz, D. A. Millichamp and A. L. Harris, describes in considerable detail the sleeping, eating, washing, dressing, play and elimination routine of the children, and the way problems which arose were solved. Sample charts and records are presented.

The sixth paper on early development in spoken language of the quintuplets, by W. E. Blatz, M. I. Fletcher and M. Mason presents data collected from the 12th month. Every new sound which each child made was recorded by the staff in charge. A complete chart for each child is contained in an envelope on the back cover. The quintuplets were found to be slow in starting to use syllables and words, as compared with a control group of 13 children.

Many photographs of the quintuplets at various ages, and their environment are included.

AMERICA'S YESTERDAY.

By F. Martin Brown. J. B. Lippincott Co., Philadelphia. $3.50. 9 x 6; 319 + 32 plates; 1937.

The science of archaeology has never been adequately synthesized. This is particularly true of American archaeology. Except for a work by Alphaeus Hyatt Verrill that did not enjoy the popularity it deserved, this is probably the first work of the kind to appear. That it was badly needed is shown by the surprising conclusions reached by combining the findings of separate investigators.

The author believes that man has been in America a much longer time than commonly supposed. On the basis of the Folsom flints, the association of the bones of the Natchez man with those of the ground sloths, and the occurrence of human bones in the glacial drift of Lake Agassiz, he concludes that man appeared in America during the first interglacial. This primitive American was in no way essentially different from *Homo sapiens* but *Homo sapiens* did not arrive in Europe until the third interglacial. All older Europeans were Neanderthal men, a type not known in America. We must therefore conclude either that the geologists who correlated the glacial gravels of America and Europe have widely missed the mark, which seems highly improbable in view of the quantity of study that has been done on this subject, or that *Homo sapiens* has been established in Europe since the Chellean, or that America was inhabited by a race of submen ancestral to *Homo sapiens*. No empirical evidence in support of either of these latter contingencies has ever been discovered.

Concerning the origin of American civilization the author takes a more conservative view. He agrees with most other anthropologists that American civilization is indigenous, as evidenced by the lack of the domestic animals and plants of the old world prior to the coming of the conquistadores. The age of American civilization he estimates at 4000 years, though conceding that this figure may have to be revised when the age of the pedregal at Cuicuilco is known. He seems ignorant of the study of the pedregal made by Mena and Hyde, who put its age at 5000 years, that of the loess below it at 2000, and the cultural age of the artifacts from beneath the loess at about 1000, making 8000 altogether. Also he ignores the excavations carried on by the University of Arizona, which disclosed that the pyramid of Cuicuilco is only the last of four placed in cone-in-cone formation.

It is obviously impossible to include in a book of this size everything that every reader will wish to know about, and many will be disappointed to find no mention of the artifacts from the Delaware gravels found by Xantus in the fifties of the last century, or of the Lenape Stone with its engraving of the two hunters attacking a mastodon. Also, many readers will wish to question the statement that of the four native governments developed on this soil that of the Incas was communistic, that of the Mayas oligarchic, that of the Aztecs autocratic, and that of the Pueblos democratic. This is important if true, for the democratic Pueblos alone survived the conquest. But since the Maya empire disappeared before the Spaniards arrived, and since the Spaniards made every effort

to eradicate the memory of their past glory from the minds of the natives by burning their books and burying their pyramids, it is difficult to see how such definite appraisals of these political systems can be made. At least one authority, Hewitt, has denied that the Aztecs were autocratic.

These criticisms are not intended to be derogatory—the point is that this is the kind of book that makes the reader think. No one interested in American prehistory can afford not to read it. It is well written and the illustrations are excellent, only there are not enough of them. There is a complete index, two chronological tables, a bibliography, and a chapter on tree-ring dating.

CASTE AND CLASS IN A SOUTHERN TOWN. *By John Dollard. Institute of Human Relations, Yale University Press, New Haven; Oxford University Press, London.* $3.50. 9 x 6; vi + 502; 1937.

The research site was an unnamed Southern town having a population slightly in excess of 2500; and the information was assembled by means of interviews that took place in an office maintained especially for that purpose by the author, in the homes of the informants, or at social gatherings of one sort or another. Since the object was to obtain a fairly representative cross-section of both white and Negro opinion, it necessarily follows that the writer had to remain on good terms (while in a southern town) with members of both races.

The bias of the various informants is readily admitted at the outset. Many of the whites were suspicious of the author's motives, yet were, in varying degrees, anxious that their side of the case be adequately presented; the Negroes, on the other hand, were often aware of the possibilities of favorable publicity for their cause that might come from any such sociological investigation.

In the chapter on "Bias" the author has inserted the following as a footnote: "The writings and views of Freud have become so thoroughly worked through my thikning that I had rather ascribe to him a major orientation of my thought than cite him as frequently as I would otherwise have to."

There are chapters on caste and class; caste patterning of education; caste patterning of politics; accommodation attitudes of Negroes; aggression within the Negro group; Negro aggression against whites; white caste aggression, etc.

Probably what is brought out most clearly is the extraordinary pressure that the whites bring to bear on the Negroes in order to make them conform to certain behavior patterns. At this point it might be noted that statistics on lynching are not as significant as reformers would have us believe, for the Southern whites can and do make the Negroes conform without resorting to that extreme measure. The author shows that it is the white middle class, and not the poor whites, who are more concerned with keeping the Negro in his place. Negroes have one effective weapon against the whites, and they make use of it frequently. They clear out without giving notice, and often during the busy season. The fact that crimes of violence are numerous in the Negro quarter is partially attributed to the total lack of opportunity that any Negro has to repay a white in kind, with the consequence that he has to vent his animosities on members of his own race. Considerable point is made of the amount of sexual contact that is presumed to take place between white men and Negro women. The writer claims that one of the reasons why the whites are so harsh with Negroes is because they (the whites) fear that Negro men, given the power, would hand out to white women the same treatment that Negro women are now receiving from white men.

A few remarks on the methodology used in the study would not be out of place. While it is obvious to any intelligent reader that the race imbroglio in the South has its psychopathic aspects, and that a psycho-analytic approach could be employed to great advantage, obviously great caution must be exercised in accepting the remarks of unidentified informants, particularly on such subjects as sexual behavior, as constituting a body of facts to be used in interpreting the mores of a community.

SAVAGE CIVILIZATION.

By Tom Harrisson. Alfred A. Knopf, New York. $4.00. $8\frac{3}{4}$ x $5\frac{3}{4}$; 461 + 32 plates + 1 folding chart; 1937.

When the Oxford New Hebrides Expedition returned to England in February of of 1934, Harrisson decided to stay behind. "To me the most important thing: that I found I could live native, or near it. Their food and sleep, kava, meal-times and laughter suited me. I never have been a shoe wearer, or natural shaver. This was useful. Because I soon spent the scanty money Oxford had given me to come home with. And then I was able to live on without; a year cost £4."

The author got his training (mainly in biology) at English universities, is 25 years of age, and has been explorer since the age of 18. Certainly this is in many ways a remarkable work, whether one chooses to consider it as a travel book or as a treatise on the anthropology of primitive peoples. In 1606 the Spaniards discovered the New Hebrides, and during the 200 years that followed French and English expeditions made sporadic contacts with various island groups in the archipelago. In 1828 came the discovery of sandalwood, and the consequent launching of a period of exploitation which was characterized throughout by as vicious treatment of native populations as one can find anywhere in history. Harrisson's account is detailed, sardonic, and strictly amoral. At frequent intervals remarks of a sort not customarily made by well brought up anthropologists are injected into the narrative.

"When he took over the parish he informed his parishioners, 'religion may be compared to a coconut. The husk of ignorance must be removed and the hard shell of the love of sin must be broken by the hammer of the Word, ere the blessing could be obtained. Once secured, it is indeed meat and drink to the perishing soul.' Years later it was to be meat and drink and millions with a peerage to Mr. William Lever."

"Geddie was a Nova-Scotian, real old style hardbit Presbyterian, a fine clean intolerant tough—one hundred per cent all talking, hymning and danceless."

The author managed to get along so handsomely with the natives that just at about the time of his departure plans were afoot to convert him into a chieftain. The descriptions of native life differ in two essentials from most studies of this sort; the author actually *went native* whereas other anthropologists, in the majority of cases, do not more than delude themselves into believing that they are living *like* natives, and secondly, the elaborate rationalizations so beloved by many anthropologists are here conspicuous by their absence.

The following is Harrison's candid opinion of the work of one of his predecessors:

"The standard work on the area is Rivers' *History of Melanesian Society*. This has been regarded as a great scientific work. That is a mistake. It is only great prose. It is a brilliant piece of circular subjective reasoning and creative literature. It is the result of a short study, mostly among mission natives on board a mission yacht. Volume one is filled with anthropological data. Volume two, the same size, contains the theoretical chat about the first volume. Everything in the New Hebrides is explained (though large areas are still culturally unknown) on a perfect pattern of logic (was Quiros logical?). Everything is brought by migrations of people, 'kava people' and 'betel people' especially (Rivers never studied the botanical distribution of the betel palm, and the fact that kava *Piper methysticum* is an exceedingly close relative of *Piper betle*, which may throw simple light on the reason why the 'betel people' did not get far south. . . .).

There is an index, and an excellent bibliography.

THE ABBÉ DU BOS—HIS ADVOCACY OF THE THEORY OF CLIMATE. *A Precursor of Johann Gottfried Herder.*

By Armin Hajman Koller. The Garrard Press, Champaign, Ill. $1.75. $7\frac{1}{2}$ x $5\frac{1}{4}$; 128; 1937.

The Abbé du Bos was a remarkable man—a diplomatic representative of France by turns in England, Spain, Italy, Germany, Holland, and Belgium; secretary of the French Academy; a rival claimant against Baumgarten for the honor of being the founder of the science of esthetics. Today he is practically unknown except by a few enthusiasts.

The present work is devoted to a discussion of a bizarre theory elaborated in his *Reflexions Critiques*, which was published in 1719 when he was 49 years old. It has very little to do with climate, but

concerns itself with the factors that produce artistic genius.

Du Bos confines his discussion to the representative arts. Vitruvius and Lulli are the only presentative artists mentioned at all, and of these the first is remembered today chiefly for his technical treatises than for his artistic creations, and the second is generally not remembered at all.

Very briefly, Du Bos believed that genius was produced by changes in climate. He refers to four periods in history when efflorescences of genius have occurred—the ages of Pericles, Augustus, Julius the Second, and Louis XIV. Each of these was strictly delimited in space as well as in time, and Du Bos believes that it can be shown that local changes in climate took place in each locality both before and afterwards. But the evidence he produces is very skimpy and not convincing. All racial characteristics he attributes to the climatic environment. The Portuguese and the Negroes in the Cape Verde Islands look alike, despite the fact that there has been no miscegenation (?). Also, when the Normans conquered England and when the Franks settled in France both peoples left behind their old climate and their old racial characteristics and adopted those o the new country. Homesickness is failure to become acclimated to a new environment.

His complete neglect of the Elizabethan age in English literature detracts from the value of his theory, and the unfortunate fact that he died too soon ever to have heard of Haydn, Mozart, Beethoven or Wagner weakens it. The author of the present work is a great admirer of Du Bos but this does not blind him to the latter's weaknesses, such as his discussion of the influence of industry on climate, the composition of the atmosphere, the effect of war on civilization, etc., all of which he brings in, and on all of which he goes astray, because he lived too soon.

The work has great value, however, as the discussion of eras of genius involves the discussion of the men who made it so, and this helps to keep alive many of the great names of the past which our modern method of life tends to consign to an undeserved oblivion.

PRIMITIVE RELIGION *Its Nature and Origin. By Paul Radin. The Viking Press, New York.* $3.50. 8½ x 5¾; x + 322; 1937. Dr. Radin's book is an excellent study on aboriginal religions for three reasons: he removes his sphere of interpretation from the "intellectual vacuum" of the psychologist to a study in "terms of human personalities", not pseudo-psychological generalities; he uses first-hand descriptions, quotations from native informants, and authentic descriptions given by scholars intimately connected with certain cultures; and he quotes at substantial length for the edification of the lay reader.

He first approaches his study of the nature and origin of primitive religion through an inimical social-economic background and states that religious feeling is an "emotional correlation of the struggle for existence in an insecure physical and social environment". Therefore, primitive religion was fostered in a maternal bed of social-economic origin. Consequently when life values are sustained by other means than religious phenomena religion is divorced from mundane affairs. Religious intensity is divided into three types: true, intermittent, and indifferent, with many gradations among the second group. His division of the "mana" concept into two groups, the personal or materialistic-magical side and the impersonal or idealistic-mystical aspect, is the essence of his theory of non-homogeneity in the religious experience among members of the primitive groups. A division, therefore, is made between shaman or priest and the layman. This antithetic feeling between religious experience and pure practical function runs as an underlying current through the religious life of simple cultures to complex agricultural civilizations, up through the concepts of the soul, ghosts, and gods, and through religious formulators, magicians, priests, their esoteric rituals, and ritual dramas. An excellent bibliography completes this scholarly study.

THE NATURE OF HUMAN NATURE *and Other Essays in Social Psychology. By Ellsworth Faris. McGraw-Hill Book*

Co., New York. $3.50. 9 x 6; xii + 370; 1937.

These rambling and loosely connected essays fall into five broad categories: 1. *Group and Person*, 2. *Conduct and Attitudes*, 3. *Sociology and Education*, 4. *Sociology and Ethnology*, and 5. *The Sociology of Racial Conflict*.

To a large extent the discussions center about words (never well-defined) that have been coined by various sociologists. Great effort is expended, with very little recourse to facts, in analyzing these concepts, and in determining their validity. The word *group*, as an example, is at the start assumed to have an independent existence, and then the search is on to find what it is that corresponds to the word. From the vaguely defined *group* we pass on to *primary* and *secondary groups*. *Sect*, *imitation*, *attitudes*, *punishment*, etc. receive the same treatment. The procedure is not to start with facts, and then try to search out the uniformities among them, but rather to make facts correspond in some way to words that were never precisely defined in the first place. Behaviorism, gestalt psychology, psychoanalysis, and the psychological experimentation of physiologists all serve to release series of observations that are sometimes more dogmatic than intelligent.

But Faris has his moments of shrewd and acute criticism.

> The central doctrine of the Unconscious (impressively capitalized) appears to be a hypostatization of the notion of the subliminal which is at least three hundred years old and has received recognition ever since. But the Unconscious is presented in the books of these men as the most important aspect of human life, a rather repulsive dungeon where evil spirits are confined, to be exorcised by letting the cat out of the bag. If proof of the existence of this limbo is demanded, reference is made to the maturation of problems, a phenomenon long familiar. Men have awakened from sleep to find a difficult solution all clearly apprehended, but it can also be said that a skater has suddenly found his performance improved, though this would not mean that the Unconscious had been exercising on the ice.

Pareto is disposed of as follows:

> Although the book has no value for sociology, the student of personality should find it a serviceable document. The unintentional revelation of Pareto's coarseness, his scorn for moral principles (2316^{19}), his unfairness to opponents, his utter lack of a sense of humor, his towering egotism—all these and much more are obtrusively manifest. Some competent student should work through the material with a view to understanding the development of the personality of an old man who aspired to be the Machiavelli of the middle classes. One result of such investigation might be the explanation of why he thought he could teach the world sociology without ever having learned it, even if he must use a million words.

LATER CRIMINAL CAREERS.

By Sheldon and Eleanor Glueck. Commonwealth Fund, New York; Oxford University Press, London. $3.00. $9\frac{1}{4}$ x $6\frac{1}{4}$; xi + 403; 1937.

In 1930 the authors reported on the careers of 500 criminals after five years from their discharge from the Massachusetts Reformatory. After five more years this group has been surveyed again and the results of the investigation are presented in this volume. At the end of the second five-year period the number of apparently reformed criminals had increased from 89 at the end of the first five years to 118, that is, from 21.5 to 32.1 percent. The authors are particularly interested in trying to determine the factors associated with this increase. They have considered numerous familial and social characteristics including reformatory history, economic responsibility, intelligence, and others, but none of these seem to be correlated with the increase in reformation. *Faut de mieux* the authors conclude that since the criminals have grown older ageing is the factor responsible for reformation. Such a conclusion has very little, if any, meaning especially when from the data given it can be shown that the older criminals do not have a faster rate of reformation than the younger ones and that the age classes have contributed to the increase each in proportion to its number.

The book ends with a plea for a change in the peno-correctional system. With this everyone should agree. The study plainly indicates that after 10 years almost 70 percent of the original sample of ex-convicts are still criminally active, therefore there can be no doubt that something is radically wrong with the system. [Reginald the Office Boy says that this is a *non sequitur* if he ever saw one. The

lad becomes more useful to us every day.] While this book deals with a unique investigation on a subject of paramount interest it is a very difficult one to read. The presentation of the findings is particularly faulty.

ACROSS CYPRUS.

By Olive M. Chapman. With a Foreword by The Viscount Mersey. John Lane The Bodley Head, London. 15s. net. $8\frac{1}{2}$ x $5\frac{3}{8}$; 255 + 34 plates + 1 folding map; 1937.

A pleasant, well-written, quiet sort of travel book about a place that was much more exciting and important 2500 years ago than it is now. In a short opening chapter the author reviews the checkered history of Cyprus. One item in it has a certain pertinence at this moment. It shows once more how very recurrently human beings are wont to behave. Also it calls to mind those classic lines

How odd
Of God
To choose
The Jews.

In A.D. 116–117 there was an insurrection on the part of the Jews, who at that time comprised a considerable part of the population. They brutally massacred thousands of the Greeks, and it was two years before the revolt was finally suppressed by the Roman Governor Lucius. During that time a quarter of a million of the inhabitants of Cyprus are said to have been slain. All Jews were eventually expelled from the island by order of the Senate. So bitter was the feeling against them that for a great number of years afterwards no Jew was allowed to land in Cyprus, and if any of their race were found on the island they were immediately put to death, even though, as sometimes happened, they were shipwrecked near the coast and forced by circumstances to land. The result of this long-engendered spirit of revenge has left its mark, for as late as 1911 the total number of Jewish subjects in Cyprus amounted to only one hundred and ninety-three persons.

THE GEOGRAPHY OF EUROPE.

By George D. Hubbard. D. Appleton-Century Co., New York and London. $5.00. $8\frac{3}{4}$ x 6; xii + 876 + 1 folding map, 1937.

In these days of tension and general unrest, when "the political situation in Europe" is upon the tongue of everyone, it has been a relief and a pleasure to find a book which describes the countries of Europe calmly and dispassionately from the point of view "of the relation of man and his activities to the physical conditions in which he finds himself". Each of the twenty-seven major states of Europe is discussed separately from this angle, the physical conditions being classified by the author into three main categories: topography, soils, climate, distribution of land and water, elements of relief; resources, as forests, power, fuel, building materials, minerals, fisheries, wild life; neighbors and their social, economic and religious standards and status. The relation of man to these conditions is shown in a broad survey of his activities in response to such environmental features. Early geologic and physiographic history, and past races are also considered as conditioning influences on the activities of the present peoples.

While intended primarily as a text for geography students, this book with its wide range of information, its many maps, and numerous photographs well selected for depiction of scenes typical of the various countries, will be found by other specialists and the general reader alike to be both interesting and instructive. An index is included.

NATURALISTS OF THE FRONTIER.

By Samuel W. Geiser. With a Foreword by Herbert S. Jennings. University Press in Dallas, Southern Methodist University, Dallas. $3.00. 9 x 6; 341; 1937.

In this set of biographies Dr. Geiser has commemorated the careers of ten men who earned varying degrees of recognition for their work as pioneer naturalists and collectors in the southwest during the years 1820–1880. These ten contributors to the advancement of natural science in a new country were Jacob Boll, Jean Louis Berlandier, Thomas Drummond, Louis Cachand Ervendberg, Ferdinand Jakob Lindheimer, Ferdinand von Roemer, Charles Wright, Gideon Lincecum, Julien Reverchon, and Gustaf Wilhelm Belfrage. The author spared no effort in his search for accurate data on the lives and works of

these men and on the details of the history of the Texas frontier which serves as the background for these personalities. As a result of this painstaking preparation plus the author's gift for pleasant narration, we are presented with a book not only of permanent historical, biographical, and scientific value, but also of great interest.

In the first of two appendices, numerous bibliographical sources are listed for each of the ten biographies. In the second is a list containing the names of over 150 naturalists and collectors known to have worked in Texas during the period 1820–1888. Dates, notes and bibliographic references follow each name. There is also an index of names.

HUMAN AFFAIRS.

Planned and Edited by R. B. Cattell, J. Cohen and R. M. W. Travers. Macmillan and Co., New York and London. $4.25. 8½ x 5½; xi + 360 + 17 portraits; 1937.

The editors, three young men with an evident flair for vivid advertising language, have revived the old idea that the Scientist or, as Plato put it, the Philosopher should direct human social behavior. Therefore, they tried to inveigle 14 eminent scientists representing a wide variety of fields to contribute each an article on the subject of what science can do to aid in the prevention and treatment of the ills of society. As usually happens, the scientists evaded the main issue and here each presents an article of a more or less general nature and not very inspirational regarding his own field of activities. A few have entered into the spirit of the occasion by tacking to the end of their articles a paragraph or two in which the scope of this symposium is restated. The 14 scientists represent biology (J. B. S. Haldane), psychology and psychiatry (D. Katz, E. Chambers, E. Miller and W. McDougall), social sciences (A. S. J. Baster, M. Ginsberg, K. Mannheim and the Earl of Listowel), anthropology (Lord Raglan and B. Malinowski), eugenics (C. P. Blacker), medicine (H. Brackenbury) and sexology (Havelock Ellis). The senior editor also contributes with an article on education. Each article is accompanied by a photograph of the author whose biography is briefly given in an appendix.

RESEARCH MEMORANDUM ON CRIME IN THE DEPRESSION. *Bulletin 27.*

By Thorsten Sellin. Social Science Research Council, 230 Park Ave., New York. $1.00. 9 x 6; vii + 133; 1937 (paper).

RESEARCH MEMORANDUM ON SOCIAL ASPECTS OF HEALTH IN THE DEPRESSION. *Bulletin 36.*

By Selwyn D. Collins and Clark Tibbitts with the Assistance of Arch B. Clark and Eleanor L. Richie. Social Science Research Council, 230 Park Ave., New York. $1.00. 9 x 6; xiii + 192; 1937 (paper).

These are two of the series of monographs sponsored by the Social Science Research Council to stimulate the study of the social effects of the recent economic depression. The first reviews the results of some of the investigations on the relation between economic conditions and crime trends and critically discusses the sources of error which effect such investigations. The author outlines in some detail what he considers are the studies needed to illuminate the problem of the effects of economic changes both on the manifestations of criminality and on the making and execution of laws.

A similar pattern of exposition is followed by Collins *et al.* in their discussion of health and disease in relation to the depression. These authors summarize some of the observations made regarding changes in mortality and morbidity during the depression, and the relation of economic condition to health status. They also describe the extent of the organization of medical care by private and public means.

SOCIALIZED MEDICINE IN THE SOVIET UNION.

By Henry E. Sigerist. W. W. Norton and Co., New York. $3.50. 8½ x 5⅝; 378 + 16 plates; 1937.

This is a portrayal of the progress of medicine and, in particular, of public health

measures in Soviet Russia. It is written with such exaggerated expressions of uncritical admiration as to appear in parts not the work of an eminent historian but rather the panegyric of a Rotarian speaking of "our fair city". In the first chapter is given a condensed discussion of Marxism and Leninism, followed by a description of the state of medicine and public health in czarist Russia. In the following chapters Sigerist reports on the present system of medical teaching and practice and the ways and means adopted to safeguard the public health. Without doubt there has been progress in the health conditions of Russia during the last 20 years, but how great it has been and to what extent it is an achievement possible only in a Soviet state is impossible to say. The Russian government is uncommonly reticent in publishing vital and health statistics and Sigerist gives none to speak of. Since the author's statements are based either on limited observations or else on plans which have yet to be executed, this book cannot be utilized as a means of realistically evaluating socialized medicine.

HANDBOOK OF NORTHERN ARIZONA POTTERY WARES. *Museum of Northern Arizona, Bulletin No. 11.*

By Harold S. Colton and Lyndon L. Hargrave. Northern Arizona Society of Science and Art, Flagstaff, Ariz. $4.00. $8\frac{1}{4}$ x $5\frac{1}{4}$; xiv + 267; 1937.

An attempt has been made in this work to analyze the pottery types that are found on the pleateau of Northern Arizona. Large numbers of sherds have been found in this area, but the lack of a system of classification has resulted in a great confusion of descriptions and names. In an effort to bring order out of chaos, and to establish a standard technique of procedure for workers in the field, the authors have defined a few terms (such as "type", "ware", "series") which have hitherto been rather loosely used; have proposed rules for the determination of names to be adopted; have sorted and analyzed the available mass of material, and have constructed a key for use in the identification of southwestern pottery types. The major portion of the book is devoted to descriptions of pottery types and wares of the area delimited, each description following a standard arrangement for the presentation of each character. Glossary, bibliography, and index are provided.

EARLY MAN *As Depicted by Leading Authorities at the International Symposium at the Academy of Natural Sciences, Philadelphia, March 1937.*

Edited by George Grant MacCurdy. Introduction by John C. Merriam. J. B. Lippincott Co., Philadelphia. $5.00. 9 x 6; 362 + 27 plates; 1937.

This volume presents the contributions of foreign and American investigators to a symposium on Early Man. The fact that 36 papers were read is indicative of the success of the congress, but the list of authors is not entirely representative of the world's students of the problem. The subject matter includes papers on the relics of Early Man in Java, America, the Near East, Norway, China, India and Australia. There are also a number of articles discussing problems of Pleistocene stratigraphy. The eminence of the authors, among whom are included Hrdlička, Keith, Gregory, and Dubois, is a sufficient guarantee of the quality of the papers which, in general, are written in an interesting manner. The majority of papers dealing with Early Man proper report on the evidence of the antiquity of man in America. In view of some differences of opinion among the students, a final summary of all the facts and theories on this topic would have been helpful.

THE ANATOMY OF MURDER. *Famous Crimes Critically Considered by Members of the Detection Club.*

By Helen Simpson, Margaret Cole, Dorothy L. Sayers, John Rhode, E. R. Punshon, Francis Iles and Freeman Wills Crofts. The Macmillan Co., New York. $2.50. $8\frac{3}{8}$ x $5\frac{5}{8}$; vii + 336; 1937.

This volume consists of the stories of seven murders—some famous, others un-

known to the general public—written by an equal number of members of the Detection Club. As is only natural in such a collected volume, there is a great diversity both in the style of the writers and in the manner in which the crimes are treated. Some of these studies offer an excellent opportunity for the reader of detective stories to exert his mind in piecing together fragmentary evidence, while others offer fascinating character studies for those more interested in the personality and motives of the criminal than in the mere mechanics of the crime.

The work of Dorothy Sayers and that of Francis Iles is especially commendable. The former writes of an almost inconceivable murder in a humdrum and respectable home, and the latter of an exotic crime in a weird and completely abnormal household. Most of these accounts rise far above the average murder mystery, and several are not only excellently, but also amusingly, written.

LIFE AS A WHOLE.

By J. W. Bews. Longmans, Green and Co., New York. $6.00. 8½ x 5½; ix + 347; 1937.

In this book the author, professor of ecology in Natal University College, approaches the study of the life of man with ecological methodology—separate excursions guided by expert leaders into various aspects of life, collection of facts and observations, and finally a synthesis of the parts into an integrated whole. The scope of the book is remarkable. Viewpoints glanced at include physical chemistry, evolution, neurological physiology and psychology, and endocrinology. Autecology (the life history of man, with emphasis on transitional periods), from birth to old age is studied. Man's works, a reflection of his life in the world, are considered—his material works, his social life and institutions, and his philosophies. Finally the study of man's art, architecture, sculpture, painting, music and great literature is undertaken. The material is necessarily presented briefly, but with commendable objectivity and balance. An excellent bibliography is appended and the book is well indexed.

PRESSION SOLAIRE ET ASTROPHYSIQUE. LES MALADIES DE LA NUTRITION. *L'Eau en Physique et Biologie.*

By G. Froin. Girardot et Cie, Paris. 35 francs. 9½ x 6¼; 352; 1937 (paper).

This is the last of a series on astrophysical influences on life, dealing in particular with solar, lunar and other astral factors in the causation of nutritional diseases. These are too complicated to treat adequately in this review. However, incidentally, the author has found an ingenious explanation of the color of the various races by the hypermagnetic light waves from the planets diffracted through the moon to different areas of the earth. Thus, red and orange waves striking the Americas explain the "red" of the Indians. [Footnote 1: "It is probable that the whites who have migrated to America will in time assume a red color, provided they do not cross-breed with other whites and yellow races."] Yellow rays landing in Eastern Asia account for the skin-color of the Mongolians; the greens and blues strike Europe, forming the complimentary white. Africa receives no magnetic light waves, and hence its inhabitants are black.

RAPPORT SUR LE PÈLERINAGE DU HEDJAZ *de l'Année de l'Hégire 1355 (A.D. 1937).*

Conseil Sanitaire Maritime et Quarantenaire d'Egypte, Alexandrie. Free. 12½ x 9¼; 147 + 5 plates + 5 folding tables; 1937 (paper).

The flight of Mohammed from Mecca to Medina in 622 A.D. is celebrated annually by a pilgrimage of faithful Mohammedans to Hedjaz. During the past decade, a careful study has been made of the general health of the pilgrims, and of the hygienic and sanitary conditions under which they make the journey. This paper is the tenth annual report, the plan of which was originated at the International Sanitation Convention of Paris in 1926.

The study includes a statistical report of the numbers of pilgrims from the various countries, by sex; the methods of travel; a description of the sanitary conditions of boats; a discussion of the medical precautions taken; and the morbidity and mortality during the pilgrimage. In

comparison with reports of previous years, the report for 1937 shows that ever increasing precautions are taken to safeguard the health of the travellers, and that the mortality from infectious diseases among them is almost nil.

ADVENTURES IN THE EAST.

By Lili Körber. John Lane The Bodley Head, London. 12s. 6d. net. 8½ x 5½; 347; 1937.

The original German volume *Begegnungen in Fernem Osten* from which this translation was made, was first published in 1936, following the author's return from a few months' visit in China and Japan. The trip had been an objective one, made for the purpose of a close range study of political and social conditions in these countries, and this book records the results of such a study as made by a wide-awake, intelligent and highly observant newspaper woman. But while the serious effort to portray an illuminating picture of the forces at work in shaping the history of these nations is underlying throughout the text, the author has by no means limited herself to a discussion of grave problems. Vitally interested in all matters of the moment, and intrigued by people as individuals, she tells a delightful story of her experiences as a traveler and adds much of human interest in the story of her social contacts and friendships made during her visit to the Orient.

MORTALITY TRENDS IN THE STATE OF MINNESOTA.

By Calvin F. Schmid. University of Minnesota Press, Minneapolis. $3.50. 9 x 6; ix + 325; 1937.

This is a thorough and fairly complete exposition of the changes in mortality as observed in Minnesota from 1910 to 1935. From the official vital statistics, mainly, the author has compiled data regarding the trends of the total mortality in Minnesota according to cause, age, sex and season and when possible compared these trends with those for the United States. Data on infantile and maternal mortality are also presented and compared with those for the population of the United States as a whole. A more detailed study of the mortality in Minneapolis and St. Paul is also included. There is an appendix containing information regarding metereologic conditions of the state and the description of a method of allocating births and infant deaths according to residence. The basic data here presented should be very useful as a starting point for investigations on the demography of Minnesota.

COLONIAL POPULATION.

By Robert R. Kuczynski. Oxford University Press, London. $1.75. 8¾ x 5½; xiv + 101; 1937.

This is a compilation and discussion of official data on the total population of all colonies and mandated areas, as well as its distribution by race and by continent of birth. A brief description of the state of birth and death registration in each colony is also included. As the author points out in his introduction the official data for different colonies are of very unequal value. A few are based on carefully taken censuses, others on censuses inadequate in execution or including only part of the population, others on estimates of varying adequacy—as late as the 1920's the estimate of the population of Hong Kong was based on the amount of night-soil collected—while still others lack any factual basis. The student of population may well be grateful to the author for assembling in one volume data for which he would otherwise have to hunt through many publications, some of them not easily obtainable.

THE NEGRO'S STRUGGLE FOR SURVIVAL. *A Study in Human Ecology.*

By S. J. Holmes. University of California Press, Berkeley. $3.00. 9¼ x 6; xii + 296; 1937.

Holmes examines the trends of birth, death and growth rates of the Negro population of the United States. He believes that the increased growth rate be-

tween 1920 and 1930 was real and was stimulated by the decrease in foreign immigration. If the restrictions against foreign immigrants are maintained and the birth-rate of the whites of the rural south continues to decrease it is probable, the author believes, that the Negro population will increase at an even greater rate. In addition, if the present Negro morbidity and mortality can be considerably reduced then the United States will be faced with the problem of how to regulate the Negro-white population balance. The author is well aware that at present there is no adequate basis for future predictions and therefore he limits himself only to an outline of the possibilities. The book contains an extensive bibliography.

CAPTAINS AND MARINERS OF EARLY MARYLAND.

By Raphael Semmes. Johns Hopkins Press, Baltimore. $5.00. 9½ x 6¾; xvi + 856; 1937.

An account of various phases of the social history of seventeenth-century Maryland, largely verbatim quotations from the original sources. We are still uncertain whether the "Captains" of the title refers to Captains of vessels or of militia companies. Both subjects are dealt with, as well as the game that furnished the colonists with much of their meat, the fur trade, the frequent disputes between the Governors and the Assembly, the struggle between Claiborne and the authorities of Maryland over the possession of Kent Island, and the relations of the colonists to the neighboring Indian tribes. There is little attempt at synthesis, but the reader receives a vivid impression of life in early Maryland.

THE IRISH COUNTRYMAN. *An Anthropological Study.*

By Conrad M. Arensberg. Macmillan Co., New York. $3.00. 8½ x 5⅜; xi + 216; 1937.

This book is a series of Lowell Institute lectures. There are chapters on the countryman at his work, the family and its relationship to land holdings, the ties between family members, and the functions of shops, pubs, and fairs in Irish rural community life. The material is well organized, and the style of writing, even when the author holds forth upon the new anthropology, is unusually clear. In the author's view anthropology "has become a behavioral, or better, an operational science, to use a term Bridgman has introduced into the natural sciences." It is not, however, easily apparent from the results that the concrete application of this philosophy has led to any strikingly different conclusions than have been reached by older anthropological and sociological approaches.

There is no index.

THE HUMAN BODY. *Third Edition, Corrected, Enlarged, and Rewritten.*

By Logan Clendening. Illustrations by W. C. Shepard and Dale Beronius. Alfred A. Knopf, New York. $3.75. 9¼ x 6¼; xv + 443 + ix; 1937.

This book appeared before us ten years ago, and after having been corrected and enlarged has returned to us again for our edification. In his foreword Dr. Clendening announces that time and increased knowledge have caused him to change practically all of his opinions and he has rewritten this book accordingly. It has enjoyed wide and deserved popularity, and bids fair to go merrily along its way for a considerable spell longer. All in all we know of no book trying to do the same thing for the general reader that is so entertaining and dependable.

A GRAPHIC SUMMARY OF THE VALUE OF FARM PROPERTY. (*Based Largely on the Census of 1930 and 1935.*) *U. S. Department of Agriculture. Miscellaneous Publication No. 263.*

By B. R. Stauber and M. M. Regan. Government Printing Office, Washington. 5 cents. 9⅛ x 5⅞; ii + 20; 1937 (paper).

This is a series of 24 maps and graphs showing the drastic changes in farm property values that have occurred during the

last quarter of a century. Figures 1–4 deal with the geographic distribution of the total value of all farm property and its division according to classes. Figures 5–15 show various aspects of the changes in value of farm real estate, while figures 16 to 21 illustrate the distribution as well as changes in the value of farm real estate —lands and buildings. The three final figures deal with farm-dwelling values for 1930 only, the one year for which data were available.

TASCHENBUCH DER RASSENKUNDLICHEN MESSTECHNIK. *Anthropologische Messgeräte und Messungen am Lebenden.*

By Bruno K. Schultz. J. F. Lehmanns, Munich and Berlin. 6 marks (In Germany); 4.50 marks (Outside of Germany). $7\frac{1}{2}$ x 5; 102; 1937.

This is a pocket sized hand-book based on Martin's two volume text of anthropology. The author has divided the book into two sections, one dealing with the instruments and technique of taking measurements and the other with the technique of body measurements on the human body. At the end of each section references are given to Martin and other authors. The book should be of great use in the class-room because of its convenient size and the ease with which it can be consulted.

LE PROFIL GRAPHIQUE DES INDIVIDUS ET DES GROUPES. *Normalité et Anormalité. Actualités Scientifiques et Industrielles 423. Exposés de Biométrie et de Statistique Biologique, X.*

By Alfredo Niceforo. Hermann et Cie, Paris. 12 francs. 10 x $6\frac{1}{2}$; 51; 1937 (paper).

The author discusses a graphic method of representing synthetically how an individual or a subgroup deviates with respect to a series of characteristics, body measurements for example, from the general population. The method has already been adopted by psychologists and the author illustrates its application to various studies in that field as well as to studies in anthropology and demography. It is a useful statistical tool.

AFRICA'S GOD. *VI—Uganda. Anthropological Series of the Boston College Graduate School, Vol. II, No. 3.*

By Joseph J. Williams, S.J. Boston College Press, Chestnut Hill, Mass. $1.00. $9\frac{3}{4}$ x $6\frac{1}{2}$; 44; 1937 (paper).

The author comes to the conclusion: "that in Uganda the Supreme Being of former days has lost much of His standing by the condition of retrogression in religious practices;" and, "there is much to be said in favor of the supposition of Monsignor Gorju that the monotheistic beliefs of Uganda are to be attributed to a Hamitic influence which was brought in from Christianized Nubia."

THE HIGHVELD CLIMATE.

By L. E. Hertslet. Publicity and Travel Bureau, South Africa House, London. $9\frac{5}{8}$ x $7\frac{7}{8}$; 8; 1937 (paper).

"A Challenge to the World!" This pamphlet consists of six pages of statistics on the sunshine, temperature, wind, and other atmospheric conditions of the Highveld of South Africa, and boasts of its modern conveniences, its accessibility to other parts of the world, and its scenic and scientific interests.

DIE EIGENWELT DES MENSCHEN. *Bios, Band VIII.*

By Hans Petersen. Johann Ambrosius Barth, Leipzig. RM. 2.25. $9\frac{1}{4}$ x $6\frac{1}{4}$; 28; 1937 (paper).

This is a philosophical treatment of biocenosis, attempting to apply von Uexküll's environmental theory to man. The author attributes to Plato instead of Aristotle the expression that man is a *Zoon politicon.*

ZOOLOGY

WILD ANIMAL WORLD. *Behind the Scenes at the Zoo.*

By Raymond L. Ditmars and William Bridges. D. Appleton-Century Co., New York and London. $3.00. 8¼ x 5½; x + 302 + 16 plates; 1937.

MAMMALS OF CIRCUS AND ZOO. *Including a Curriculum Unit on Mammals of Circus and Zoo Developed in the Saratoga Union School. Science Guide for Elementary Schools, Volume III, Number 6.*

By Edith A. Pickard. California State Department of Education, Sacramento. 15 cents. 9 x 6; iii + 57; 1937 (paper).

In the first of these books the authors have drawn aside the hypothetical curtain that conceals from public gaze the most interesting part of the modern zoo. They personally conduct us through the hospital, into the isolation room where the incoming acquisitions are quarantined, to the diet kitchen where meals are prepared for each according to his kind, the accident ward where the chimpanzee had a plaster cast put on its broken arm, to the surgical ward where the tiger had its teeth filled and the rhinoceros had its cataracts removed. For the modern zoo is not merely a living museum—it is a scientific institution where the inmates are not only exhibited but given the care they need to keep them fit, and where their needs and habits may be learned from observation.

There is much more to running a zoo than appears on the surface. New acquisitions may be made from time to time by purchase or exchange with other zoos, but the business of importing living animals from the jungle or the tropical islands is now so highly developed that the best exhibits are always brought in fresh from the wilds. These authors take us by proxy to the ends of the world and back, and in imagination we assist in the capture of the Komodo lizard, the Galapagos tortoises, the sea snakes (there really are sea serpents from the tropical Pacific), the Australian earthworm that is twelve feet long that Dr. Ditmars has never seen but hopes to exhibit some day, and finally we make the acquaintance of the strangest of all the animals in the zoo—the human animals that ask foolish questions and tell the director he is "all wet" because he doesn't believe that snakes swallow their young for protection and disgorge them later when danger is past, or who wish to obtain animals for vaudeville skits, or to make presents of pets that can no longer be kept at home. This book will be found interesting reading by everybody, but especially by those who like the present reviewer have had the privilege of working in a zoo themselves.

The second work is a manual for teachers who wish to give children an appreciative knowledge of what they may see in a zoo. It is a number of a monthly publication prepared by a group of teachers to help other teachers. It is highly condensed, consists largely of descriptive matter but also contains instructions on how to teach elementary zoology. Outside the teaching profession it is likely to have but little appeal.

MOSAICS AND OTHER ANOMALIES AMONG ANTS.

By William Morton Wheeler. Harvard University Press, Cambridge. $2.00. 9½ x 6; [12] + 95; 1937.

The manuscript of this book by our lamented co-editor was delivered to the publisher only a few days before his death. It is a contribution of the first rank of importance, fittingly capping the life work of one who was universally recognized at his death as the foremost student of ants in the world.

The volume deals with a colony of a fungus-growing Attine ant, *Acromyrmex octospinosus* Reich, collected by Dr. Neal Weber in Trinidad. Out of a total population of 8174, it contained 164 anomalous individuals, 53 of which are unlike any previously observed anomalies among ants or among any other social insect. These exceptional anomalies appear, under Wheeler's masterly analysis, to be decisive relative to the ancient and much debated problem of caste determination. Part I describes the distribution, habits, and normal castes of *Acromyrmex;* Part II, the anomalies of *Acromyrmex octospinosus.* Part III, discusses the long controversy over the trophogenic and blastogenic theories of caste determination. The general conclusion is that: "The caste, which could have arisen in the remote

past only in response to a very special social environment and can still maintain itself only in such an environment, has somehow become genotypic."

Appendices include taxonomic notes on *A. octospinosus*, and a revision of the known non-mosaic female and worker ant anomalies.

ARISTOTLE: PARTS OF ANIMALS, MOVEMENT OF ANIMALS, PROGRESSION OF ANIMALS.

Translated by A. L. Peck and E. S. Forster. Foreword by F. H. A. Marshall. Harvard University Press, Cambridge; William Heinemann, London. $2.50 (cloth); $3.50 (leather). 6½ x 4⅛; viii + 556; 1937.

The English speaking world is greatly indebted to Dr. Peck and Mr. Forster for the translation of these fascinating treatises by Aristotle. The volume presents (1) an introduction explaining the sources of the work, and giving reasons for various meanings given words where literal translation would have been misleading, and (2) the original Greek manuscript which, page for page, is followed by the English translation.

In the *Parts of Animals*, Aristotle concerns himself with the causes that have been responsible for animals being built the way they are, and with the functions of all the parts of animals. Of course many of his conclusions are erroneous in the light of our present biological knowledge, but what is more important is that Aristotle had very keen powers of observation, and used them adequately in studying an enormous number of organisms.

In the *Movement of Animals* and *Progression of Animals* the problems of the origin of movement, and the use of certain organs in the production of motion form the bases of discussion. In each of these dissertations, as in the former one, Aristotle shows amazing ability to observe and discuss a great number of characteristics of man, beast and birds.

A PICTORIAL GUIDE TO THE FAMILIES OF BIRDS (*Including a List of the Birds of Southeastern Michigan with Their Migration Dates*). *Cranbrook Institute of Science, Bulletin No. 9.*

By Edward T. Boardman and Elizabeth Barto. Illustrated by Vera K. Boardman. Cranbrook Institute of Science, Bloomfield Hills, Mich. 50 cents. 9 x 6; 48; 1937 (paper).

This outline was prepared for use in studying the birds of Michigan, but it contains much that is of value to the beginner in identifying and classifying the birds of any section of the country. The guide is to be used in acquainting the beginner with the various groups of birds, after which it is to be discarded in favor of the more classical handbooks.

The work presents in a very brief and elementary form the distinguishing characters of 19 orders including 48 families of birds native to Michigan together with sketches of head and feet and, in most cases, with sketches of the whole bird as it appears in some characteristic position. Also included are a check list of birds of Southern Michigan; a table showing the mean date and earliest appearance of the migratory birds; and a list of field guides and general reference books of birds east of the Mississippi.

LES HUILES DE FOIE DE MORUE. *Leur teneur en vitamines A et D.*

By Paul Chabre. Preface by A. Chevallier. Masson et Cie, Paris. 36 francs. 9¾ x 6½; 207; 1936 (paper).

This is a very interesting treatise dealing solely with cod liver oil. All phases of the subject are included—the life history and appearance of the fish responsible for the production of the oil, the fishing areas, the manner of catching the fish, the extraction and purification of the product, its chemical and physical properties, and its economic importance. Special emphasis is given to vitamins A and D. The content of these important substances in the various kinds of fish is shown to vary considerably. Liver oil taken from fish that are caught off Newfoundland have more vitamin A content than those caught off the Norwegian coast. This is said to be due to the physiological state of the fish. Newfoundland fishing

occurs when the fish are well nourished and the liver is full of oil, while the Norwegian fish are caught when they are undernourished and thin. Excerpts from the pharmacopeia of various countries pertaining to cod liver oil, and a bibliography are included.

MY FRIEND THE ROOK.

By T. S. Hawkins. James Clarke and Co., London. 6s. net. $7\frac{3}{4}$ x 5; 201 + 8 plates; 1937.

The rook has many friends as well as enemies among Englishmen. In this volume are arrayed the "pros" and "cons" for this clever bird. One gathers that the chief objection comes from the farmer who fears that the rook is devouring his newly sown grain when it is really filling its crop with wireworms (larvae of the click beetle), the grub of the crane fly, etc., which find their way into the drill-hole. The author admits that the rook may do some harm to crops but he believes (as do many others) that it does far greater good in destroying the enemies of field plants.

Included in the volume are many interesting accounts of the behavior of these remarkable and likable birds and their seeming attachment to human beings and human habitations. One of the aims of the author is to dispel the curious lore that has long led to the slaughter of rooks in wholesale numbers at certain times of the year. The volume contains some interesting illustrations but is without an index.

AN ABRIDGED CHECK LIST AND BIBLIOGRAPHY OF WEST NORTH AMERICAN MARINE MOLLUSCA.

By A. Myra Keen. Stanford University Press, Stanford University, Cal. $1.50. $8\frac{1}{2}$ x $5\frac{1}{2}$; 87; 1937 (paper).

This book is valuable to biostratigraphers as a source of latitude with midpoints-of-range corrected to date and to conchologists both as a working reference or check-list and as a compilation of literature printed from 1908 to 1936 on West American recent Mollusca. The excellent bibliography is divided into six compendia: recent literature alphabetically by authors and systematically by titles; recent revisions and synopses; indispensable publications; papers on statistical methods; and map lists of the East Pacific Coast. In addition, the book contains a check-list of alphabetically arranged genera with their respective species. The author lists sub-genera without species, but as cross references to genera in order to facilitate rapid unconfused reference. Univalves and bivalves are considered separately in the check-list; chitons and cephalopods are altogether omitted. A brief discussion of statistical methods in conchology is also included.

BOMBYLIIDAE OF PALESTINE.

By E. E. Austen. British Museum (Natural History), London. 15s. $10\frac{1}{2}$ x $7\frac{1}{4}$; ix + 188; 1937.

Of the 128 species or varieties of Bombyliidae dealt with, forty-six in addition to one genus out of 31 genera, are described as new. In the appendix particulars are given of ten species or forms of these flies which probably also occur in Palestine. Many species are protectively colored (greyish, tawny-olive or sandy) when seen against the soil as a background. But other species are deep black, and whether at rest or in motion are always conspicuous. The economic importance of the Bombyliidae would seem to be very great. All species of which the life history is known, are parasites of other insects and in many cases the host is a migratory locust. Up to the present the attempt has not been made to utilize any of the Bombyliidae in combating locusts since no method has been developed which is successful in breeding the flies artificially.

DIE BLATT-MINEN MITTEL- UND NORD-EUROPAS EINSCHLIESSLICH ENGLANDS. *Bestimmungs-Tabellen aller von Insekten-Larven der verschiedenen Ordnungen erzeugten Minen. Lieferung 4 and 5.*

By Martin Hering. Gustav Feller, Neubrandenburg. Subscription price for 6

numbers: (Germany and Switzerland) 12 marks; (foreign, except Switzerland) 9 marks. 9¼ x 6¼; Lieferung 4, 337–448 + 2 plates; Lieferung 5, 449–560; 1937 (paper).

These two issues are continuations of Hering's taxonomic study of the larvae of the leaf-mining orders, which include Lepidoptera, Hymenoptera, Coleoptera, and Diptera. Part IV includes plant hosts indexed alphabetically from *Myrica* to *Rubus;* Part V, from *Rubus* to *Zinnia.* The illustrations show the shapes of the mines produced and the distribution of fecal material in relation to the pathways of the larvae. This work is a much needed contribution to the taxonomy and biology of leaf miners and is a valuable aid for preventive work in agriculture and forestry.

Crow-Waterfowl Relationships. *Based on Preliminary Studies on Canadian Breeding Grounds. U. S. Department of Agriculture. Circular No. 433.*

By E. R. Kalmbach. Government Printing Office, Washington. 10 cents. 9⅛ x 5⅞; 35; 1937 (paper).

During the crow and duck-breeding seasons of 1934 and 1935, 512 duck nests located in three selected areas of southern Alberta and Saskatchewan were observed for evidences of destruction by crows. Field observations were supplemented by stomach examination. A high percentage of egg destruction was noted, and stomach examination revealed four times as many birds and eggs eaten by adult crows of these regions as by crows living under average conditions in this country. Various factors influencing this destruction are considered and recommendations are suggested for future crow-control operations on duck-breeding grounds.

Naturgeschichte der Nordatlantischen Wale und Robben. *Handbuch der Seefischerei, Bd. III, Heft 1.*

By Ernst Hentschel. E. Schweizerbart'sche, Stuttgart. RM. 15 (in Germany); RM. 11.25 (Outside of Germany). 10½ x 7½; [6] + 54 + 10 plates; 1937 (paper).

Concise and practical, this handbook presents the essential features of a subject which is limited by lack of material for comprehensive study. Dr. Hentschel discusses the general body structure and habits of the whalebone and toothed whales, and of the walruses and seals, with specific data concerning individual forms within these groups. Little is said of their economic importance. The work contains numerous photographs and sketches. There is also an index and list of references.

Hydroids of the Pacific Coast of Canada and the United States.

By C. McLean Fraser. University of Toronto Press, Toronto. $2.50. 9⅛ x 6¼; 207 + 44 plates; 1937.

This volume contains descriptions of every hydroid species (236 species, 59 genera) known to occur along the Pacific coast of Canada and the United States together with its distribution within the area. Keys to the families, species, and genera are given. A new genus and species, four new gonangia, and two species new to the coast are described and recorded. There is an index and forty-four plates of line drawings that illustrate all of the species listed.

Zoologica. *Scientific Contributions of the New York Zoological Society, Volume XXII, Part 3, Numbers 14–20.*

New York Zoological Society, Zoological Park, New York. $1.40. 10½ x 7⅛; 99 + 6 plates; 1937 (paper).

The seven papers presented in this issue of *Zoologica* deal with a preliminary list of Bermuda deep-sea fish; echinoderms and hermit crabs collected by members of the Templeton Crocker expedition in the Gulf of California and on the West Coast of California; the caudal skeletons of some Bermuda shallow water fish; notes on feeding methods of the vampire bat; growth of Galapagos tortoises *Testudo vicina* (from 1928–1937); and lymphocystic disease in the adult common angelfish.

RECENT ADVANCES IN ENTOMOLOGY. *Second Edition.*

By A. D. Imms. P. Blakiston's Son and Co., Philadelphia. $5.00. 7⅞ x 5¼; x + 431; 1937.

The second edition of this excellent book has been enlarged to the extent of 56 pages. Twenty-seven new illustrations are included and 18 of those in the earlier edition have been discarded. The sections which have not needed revision have been left practically unchanged, but other sections have received much revision. Such changes appear in the discussion of head segmentation, the genitalia, homologies of certain of the appendages and their parts, hormones and metamorphosis, palaeontology, visual stimuli, stimulatory organs, biological races, biological control, etc.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 466. Abt. IX, Methoden zur Erforschung der Leistungen des tierischen Organismus, Teil 3, Heft 7 (Schluss). Methoden der Vererbungsforschung.* Containing following articles: *Methoden zur Züchtung von Drosophila*, by G. A. Lebedeff; *Methoden der Erforschung der Vererbungsvorgänge bei Pflanzen*, by F. G. Brieger; *Methoden und Ergebnisse bei der Züchtung von Tetriginae*, by Robert K. Nabours.

Urban and Schwarzenberg, Berlin. RM. 17. 10 x 7; 288; 1937 (paper).

This volume contains articles on methods of breeding *Drosophila* and *Tetriginae*, and methods of investigating inheritance in plants. In the latter article the author attempts to separate the fundamental features of plant genetics. He discusses cytology and also the statistical treatment of genetic material.

FUR-BEARING MAMMALS OF CALIFORNIA. *Their Natural History, Systematic Status, and Relations to Man. Contribution from the Museum of Vertebrate Zoology, University of California. In two volumes.*

By Joseph Grinnell, Joseph S. Dixon and Jean M. Linsdale. University of California Press, Berkeley. $15.00 for two volumes. 10¼ x 6¾; xii + xiv + 777 + 13 plates; 1937.

These volumes were apparently written primarily for Californians with a direct financial interest in fur, but are entertaining reading for anyone. While there is every evidence of the material being carefully and accurately collected, it is presented in a light vein and is full of anecdotes by trappers of the region. It is the sort of book that one can read for an idle half-hour. The illustrations are excellent.

THE BIRDS AND MAMMALS OF THE WESTERN SLOPE OF THE AZUERO PENINSULA (REPUBLIC OF PANAMA). *Scientific Publications of the Cleveland Museum of Natural History, Volume VII.*

By John W. Aldrich and Benjamin P. Bole, Jr. Cleveland Museum of Natural History, Cleveland. $1.75. 9¼ x 6⅛; 196; 1937 (paper).

The ecology of the Azuero peninsula is briefly discussed and it is indicated that its fauna is slightly more related to the western end of Panama (Chiriqui) than to the eastern. Annotated lists of the birds and mammals collected and observed, with descriptions of new forms and critical notes on others, are given.

ANIMAL TREASURE.

By Ivan T. Sanderson. The Viking Press, New York. $3.00. 9¼ x 6¼; 325; 1937.

Biologists will find a devastatingly adequate appraisal of this book by Mr. Loveridge, published under the title "If the Blind Lead the Blind Shall . . . ? or Reflections on Recent Reviews of 'Animal Treasure' " in the January number of our esteemed contemporary *The Scientific Monthly* (Vol. 46, pp. 16–24, 1938).

STUDIES ON THE BIOLOGY OF THE CRAYFISH CAMBARUS PROPINQUUS GIRARD. *Illinois Biological Monographs, Vol. XV, No. 3.*

By William C. Van Deventer. University of Illinois Press, Urbana, Ill. $1.00. 10½ x 7; 67; 1937 (paper).

This is a very complete account of the habits and life cycle of the crayfish. The studies were made primarily from field

observations rather than in the laboratory. Growth, reproduction, and seasonal population trends are given particular attention.

THE SPRUCE GALL APHID (ADELGES ABIETIS LINNAEUS) IN SOUTHERN MICHIGAN. *University of Michigan, School of Forestry and Conservation. Circular No. 2.*

By Bill Howard Wilford. University of Michigan Press, Ann Arbor. 20 cents. 9 x 6; 34; 1937 (paper).

THE WALKING STICK AS A FOREST DEFOLIATOR. *University of Michigan, School of Forestry and Conservation. Circular No. 3.*

By Samuel A. Graham. University of Michigan Press, Ann Arbor. 20 cents. 9 x 6; 28; 1937 (paper).

THE MORPHOLOGY, DIVISION, AND CONJUGATION OF THE SALT-MARSH CILIATE FABREA SALINA HENNEGUY. *University of California Publications in Zoology, Vol. 41, No. 25.*

By John Marshall Ellis. University of California Press, Berkeley. 10¼ x 6¾; 34 + 5 plates; 1937 (paper).

CYTOLOGICAL VARIATIONS IN THE BLOOD AND BLOOD-FORMING ORGANS OF WHITE-FOOTED MICE EXPERIMENTALLY INFECTED WITH TRYPANOSOMA CRUZI. *University of California Publications in Zoology, Vol. 41, No. 26.*

By Sherwin F. Wood. University of California Press, Berkeley. 50 cents. 10¼ x 6¾; 30 + 3 plates; 1937 (paper).

MORPHOLOGY OF THE POCKET GOPHER: MAMMALIAN GENUS THOMOMYS. *University of California Publications in Zoology, Vol. 42, No. 2.*

By John Eric Hill. University of California Press, Berkeley. $1.00. 10¼ x 6¾; 91; 1937 (paper).

BOTANY

TEXTBOOK OF DENDROLOGY. *Covering the Important Forest Trees of the United States and Canada.*

By William M. Harlow and Ellwood S. Harrar. McGraw-Hill Book Co., New York. $4.50. 9 x 6; xiii + 527; 1937. This is a taxonomic treatise intended for the commercial forester, and consequently the vernacular names used are those derived from the trade rather than from popular usage, except in a few instances where the trade name seems unusually objectionable. The use of such terms as oak, larch, poplar, cedar, and cypress each for two distinct groups of trees is of course to be deprecated, but frequently the authors had no other choice In such cases they give notes of warning, but it cannot help but be confusing to the reader to find the names "laurel" and "arbutus" applied not to the plants commonly designated by those names, but to the aguacate and the madrone respectively. Incidentally, how did the name "arbutus" come to be applied to the mayflower in the first place?

Only native trees are covered, and of these only those which serve utilitarian purposes. There is no mention of the numerous naturalized acacias and eucalypti, and none of the palms. The gingko appears, on account of its singularly isolated taxonomic position. Also, there seems to be some doubt as to what constitutes a tree. The poison ivy is conspicuous, but the closely related round leaved sumach which grows like a bush is omitted.

The trees which are included are well described, and their identification will offer no difficulty. Their leaves, bark, fruit, flowers, and seeds are well illustrated with photographs. The authors seem to have leaned heavily on the classical work of Sargent, even to reproducing one of the typographical errors of that work. A bibliography of eleven pages and an index of nineteen pages completes the work.

USEFUL PLANTS AND DRUGS OF IRAN AND IRAQ. *Field Museum of Natural History, Publication 387. Volume IX, Number 3.*

By David Hooper with notes by Henry Field. Field Museum of Natural History, Chicago. $1.50. 9½ x 6¼; 173; 1937 (paper).

THE NORTH AMERICAN SPECIES OF RUMEX. *Field Museum of Natural History, Publication 386. Volume XVII, Number 1.*

By K. H. Rechinger, Jr. Field Museum

of Natural History, Chicago. $1.50. 9½ x 6¼; 151; 1937 (paper).

This catalogue of plants and drugs of Iran and Iraq makes interesting reading. The material was obtained by three groups of collectors during the past eight years from bazaars, markets, fields and gardens in the Near East. Information was obtained and is here recorded regarding the use of these plants and drugs (nearly 300 plants, 15 drugs of mineral origin and about the same number of animal origin) in the treatment of diseases and in prescriptions for various ailments. No new drug plants were found. This can hardly be considered strange, however, since the search for curative drugs and palliatives in the Iran and Iraq regions undoubtedly dates far back into prehistory. The report, which is without index, concludes with an alphabetical list of native plant names with Latin equivalents.

In the second of these publications of the Field Museum the author has attempted to bring up to date the classification of the North American species of *Rumex*. He has recorded 49 species and four hybrids. The most recent previous monograph on the subject mentions only 21 species. Besides detailed description of the species the author includes a key and a general discussion of *Axillares*.

La Botanique Canadienne a l'Époque de Jacques Cartier. *Contributions du Laboratoire de Botanique de l'Université de Montréal, No. 28.*

By Jacques Rousseau. Henry G. Fielder, 89 Chambers St., New York; Institut Botanique, Université de Montréal, Montréal; T. Oswald Weigel, Leipzig. 50 cents. 9 x 6¼; 86; 1937 (paper).

The three voyages of Jacques Cartier to the North American continent in the period 1534–1542 were of such importance as scientific expeditions that they have been studied from many aspects. The present paper emphasizes the botanical studies made by Cartier, particularly in Canada. Although Cartier was not a botanist, his observations concerning plant life in the new world are of such magnitude and precision that they merit considerable study. The purpose of the voyages was to study possibilities of colonization, and in consequence the writings concerning plant life assume an economic note. In describing the plants, Cartier always compares them with similar species familiar to everyone in France, and tells of what importance they would be to colonists, either as food, building materials, or as general agricultural necessities. Dr. Rousseau has included in this work a brief bibliography and record of activities of many of Cartier's contemporaries and predecessors. An annotated list of plants mentioned, an extensive bibliography, and an alphabetical index to plants conclude the text.

Die Wuchsstoffe der Pflanzen. *Ein Querschnitt durch die Wuchshormonforschung. By Gerhard Schlenker. J. F. Lehmanns, Munich and Berlin.* 3.60 marks (paper); 4.50 marks (bound). 9¾ x 6½; 106; 1937.

The subject matter of this book was made possible by the discovery of growth substances in the *Avena* coleoptile. Subsequently much work has been done on these *Wuchsstoffe*, and many theories concerning them have been expounded. In this book *Wuchsstoffe A* (auxins) are considered especially with reference to methods of their qualitative and quantitative detection and to fundamental experiments performed on *Avena* coleoptiles. Auxin a, auxin b, and heteroauxin are discussed as to structural constitution, occurrence, and effect on phototropisms and geotropisms of stems and roots. Leaf movements, both epinastic and hyponastic, are also included in the discussion of the effect of growth substances in group A. In connection with phototropic phenomena in plants the Blaauw theory is discussed. The second group, *Wuchsstoffe B*, includes bios, substances that function much like vitamins, and vitamins which are considered as to their action on fungi and higher plants. The mechanism of translocation of plant-growth hormones is discussed. An excellent brief review of an important field.

A HISTORY OF AGRICULTURAL EXPERIMENTATION AND RESEARCH IN THE UNITED STATES 1607–1925. *Including A History of the United States Department of Agriculture. U. S. Department of Agriculture, Miscellaneous Publication No. 251.*

By Alfred C. True. U. S. Government Printing Office, Washington. 25 cents. 9 x 5¾; vi + 321; 1937.

A history of agricultural experimentation and research in the United States, when reduced to a volume of this size must necessarily be sketchy. However, brief though it is, one obtains from this general survey some idea of the early forces working toward the establishment of public agencies for agricultural research in this country. The movement in the states toward this end is traced from 1840 to 1875, and state agricultural research programs carried on without federal aid until 1888 are recorded in some detail. The history of the Department of Agriculture is traced from its organization in 1862 through the administrations of its six commissioners and eight secretaries of agriculture up to 1925. Following the passage of the Hatch Experiment Station Act of 1887 and the organization of the Department of Agriculture as of cabinet rank, the field of action of these agencies spread out broadly and only brief summaries are made of the principal undertakings of this period. Subject and name indices and a bibliography are included.

PLANT ECOLOGY.

By Hilda Drabble. Edward Arnold and Co., London; Longmans Green and Co., New York. $2.50. 8½ x 5½; 142 + 12 plates; 1937.

The present trend of studying plant ecology in close relation with plant physiology has been very well adapted by the author in preparing this elementary text. The volume is not intended as a substitute for a general botany text but rather to supplement it, and carry the student into the ultimately practical study of plants in relation to their environment and in relation to each other.

The book is made up of two fundamental divisions: plant physiology, which includes a detailed study of the soil and of the basic physiological processes in plants, and plant ecology, which describes plant communities. The text is well written in a style that emphasizes detail without the burden of technical terms. It is illustrated by 24 well selected photographs of typical plant communities. The volume contains a short bibliography, a list of test questions, and an index to plant names.

THE GENUS YOUNGIA.

By Ernest B. Babcock and G. Ledyard Stebbins, Jr. Carnegie Institution of Washington, Washington, D. C. $1.25. 10 x 6⅝; 106 + 5 plates; 1937 (paper).

This genus was previously considered merely as one group in the genus *Crepis*. But as it did not seem to be closely related to the other species in that genus it has at various times been segregated as the genus *Youngia*. Until the present detailed study was made, however, no characters were known other than those typical of the genus *Crepis*. In this monograph the authors have disclosed a number of distinguishing characters, among which the cytological differences are the most striking.

The authors have produced a thorough analysis which definitely establishes the genus *Youngia*. They have included a history of the genus, criteria of classification, relationships to other genera, distribution, etc. as well as detailed descriptions and discussions of the various species and subspecies. Drawings, photographs, and tables illustrate the text.

THE PHYSICAL BASIS OF MYCOTROPHY IN PINUS. *Based on a thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Division of Biology, Harvard University, and deposited with the Widener Library, Cambridge, Massachusetts, May 1, 1935. Black Rock Forest Bulletin No. 6.*

By A. B. Hatch. Black Rock Forest, Cornwall-on-the-Hudson, New York. $3.50 9 x 6; x + 168; 1937 (paper).

A work of much interest to silviculturists. After a review of the literature on the prevalence of the ectotrophic mycorrhizal habit, the factors responsible for variation in the abundance of mycorrhizae, and the theories of mycotrophy, the author discusses the methods now in use in investigating the mycorrhizal relationships and the results of various soil culture experiments. His work shows the inadequacy of the so-called organic nitrogen theory, the errors in the pathogenic theory, and strengthens and extends the so-called mineral salt theory first postulated by Stahl in 1900. The experiments also show that instead of retarding development mycorrhizal fungi stimulate root development and that "trees are dependent on symbiotic association with mycorrhizal fungi for several soil nutrients, and therefore for their existence, in all but the most fertile soils."

ABC OF AGROBIOLOGY. *The Quantitative Science of Plant Life and Plant Nutrition for Gardeners, Farmers and General Readers. By O. W. Willcox. W. W. Norton and Co., New York.* $2.75. 8 x 5½; 323; 1937.

According to the author, agrobiology is a new science. It is the science that acquaints us with two scales: one to measure the vital energy residing in cultivated plants; the other to measure "the crop-producing values of the factors that enable plant life to expand." The book described these scales and the methods of derivation as well as enumerating the various growth factors involved. Then, having stated these "universal verities of nature," it shows how they are applicable to the main problems of farmers and gardeners. Though dealing with somewhat technical material, the book has been written in as simple language as possible so that not only serious students, but also the "gardeners, farmers and general readers" for whom it is primarily designed may benefit to the utmost. The text is clearly illustrated with tables, graphs, and diagrams, and is indexed.

A LEAF KEY TO FLORIDA BROAD-LEAVED TREES. *Native and Exotic, except Palms. By Mary F. Barrett. Illustrated by E. Bradley Tuttle.* (Obtainable from M. F. Barrett, 57 Union Street, Montclair, N. J.). $1.00. 9¼ x 6⅛; 79; 1937 (paper).

Over 600 Florida species have been keyed in this booklet, most of which are readily found either growing wild or in parks or botanical gardens. The key has been made entirely on the basis of leaves. They are more abundant and are present a longer time in the year than either fruit or flowers. Eight plates of clear pen and ink drawings supplement the text. Although both botanical and common English names have been given in the detailed index, this is arranged alphabetically only by the botanical nomenclature and therefore offers rather a problem for the uninitiated.

A TEXTBOOK OF PLANT VIRUS DISEASES. *By Kenneth M. Smith. P. Blakiston's Son and Co., Philadelphia.* $5.00. 8 x 5⅜; x + 615; 1937.

About 135 plant viruses are described as to their properties, modes of transmission, distribution, and diseases they cause in this comprehensive treatise of the subject. Viruses which are chiefly associated with a particular host plant are grouped together. For convenience, the host plants, together with a brief description of the symptoms of the disease and the virus causing it, are listed alphabetically at the end of the book. There is also a general index and indices of authors and viruses. This is an indispensable book for the plant pathologist.

BRITISH STEM- AND LEAF-FUNGI (COELOMYCETES). *A Contribution to Our Knowledge of the Fungi Imperfecti Belonging to the Sphaeropsidales and the Melanconiales. Volume II. Sphaeropsidales. Comprising Sphaerioideae, with Coloured Spores; Nectrioideae, Excipulaceae, and Leptostromataceae; and Melanconiales.*

By W. B. Grove. The University Press, Cambridge; Macmillan Co., New York. $6.00. 8½ x 5½; xii + 407; 1937.

This completes the author's detailed morphological account of British fungi belonging to the orders Sphaeropsidales and Melanconiales. (Vol. I noticed in Q.R.B. Vol. II, No. 1.) Descriptions of all known species are given together with their geographical distribution, and numerous illustrations are included. The volume also contains the following indices and lists: Ascomycetes; Ascomycetes that have a discomycetous affinity; hosts; index of binomial names; and a list of the most important authorities' names which are usually abbreviated in citations. A basic reference source for the mycologist.

PRINCIPLES AND METHODS OF TREE-RING ANALYSIS. *Carnegie Institution of Washington Publication No. 486.*

By Waldo S. Glock with a foreword by A. E. Douglass and a contribution by G. A. Pearson. Carnegie Institution of Washington, Washington, D. C. $2.00 (paper); $2.50 (cloth). 10 x 6⅞; viii + 100 + 14 plates; 1937 (paper).

The work of Dr. A. E. Douglass of the University of Arizona, who began as an astronomer, becoming in succession a meteorologist, a botanist, and an archaeologist, needs no introduction. His book in two volumes describing his method of tree-ring identification and its use in dating the pueblos of the southwestern states has been out of print for many years, and this work by one of his associates fills a great need. Its numerous illustrations are beautifully executed, its bibliography and index each covers three pages, and it will be welcomed everywhere.

FOUNDATIONS OF SILVICULTURE UPON AN ECOLOGICAL BASIS. *Second Edition.*

By James W. Toumey and Clarence F. Korstian. John Wiley and Sons, New York; Chapman and Hall, London. $4.50. 9 x 6; xxi + 456; 1937.

In this important textbook the late Professor Toumey combined the researches of the forester and the ecologist into a substantial basis for the practice of American silviculture. In the present revised edition there has been a considerable rearrangement of the sections and the division of the book has been changed from two to three parts. Part I (10 chapters) deals with the environment of the forest; Part II (2 chapters) with the influence of the forest on its environment; and Part III (6 chapters) with the forest itself. The volume includes an appendix of common and technical names of trees, a useful bibliography of 32 pages, and an index.

PLANT LIFE FORMS.

By C. Raunkiaer. Translated by H. Gilbert-Carter. Oxford University Press, New York; Clarendon Press, Oxford. $2.00. 9¾ x 6¼; vii + 104; 1937.

Although the original work of which this volume is a translation was written in 1907, it has not grown out of date, nor will it in all probability ever do so, because of the care and accuracy shown in the research upon which it is based. Like many other botanists, Raunkiaer early saw the necessity of the classification of plants into groups of finer distinction than simply trees, shrubs and herbs. In consequence, he set about the enormous task of classifying all plants according to their life economy, i.e., their adaptations to adverse conditions in their environment. His interest was those structural characteristics that reflect the essential relationships of plants to climate. No emphasis is placed upon mere structure as such. But particular structures are appraised as assets or liabilities to the plant in its struggle for existence. The text is abundantly and well illustrated. There is no index.

WEEDS, WEEDS, WEEDS.

By Sir Charles V. Boys. The Old Westminster Press, London. 1s. 2d. net. 8½ x 5½; 69; 1937 (paper.)

This pamphlet by one of the grand old men of British science is not written with the detached impersonality of a scientific

botanist. It is a pleasant but very practical account of the author's own experiences with gardening, and is designed to help both the amateur and the professional gardener, but especially the former. Various common weeds such as plantains, dandelions, yarrow, and docks are considered. Each is taken up separately, described from the point of view of its nuisance-value, and a partial or complete cure prescribed. Since the information contained in the text is almost exclusively from the author's experience, it is obvious that all weeds cannot be included. It is delightful reading, besides being tough on weeds.

THE POTATO *Its Culture, Uses, History and Classification. Fourth Edition Revised.*

By William Stuart. J. B. Lippincott Co., Philadelphia. $3.00. 8¼ x 5½; xv + 508 + 4 plates; 1937.

This fourth edition of a standard text, now well established as the classic in its field, has been extensively revised, since its last preceding appearance, in respect of six of its chapters. Otherwise it stands much as before except for minor changes to bring it up to date. We wish it the continued success that it merits.

PLANT SCIENCE MANUAL.

By Francis Ramaley. Obtainable from Francis Ramaley, Boulder, Colorado. 50 cents. 58; 9 x 6; 1937 (paper).

This is a pamphlet designed for use in a beginners course in botany. It gives specific directions for the laboratory work, leaving virtually nothing to the ingenuity of either teacher or student. The work covers the territory included in the usual elementary course.

A LIST OF MISSOURI FUNGI *with Special Reference to Plant Pathogens and Wood-Destroying Species. University of Missouri Studies, A Quarterly of Research, Volume XII, Number 3.*

By Willis E. Maneval. University of Missouri, Columbia. Single copies $1.25; annual subscription $4.00. 10½ x 7¼; 150; 1937 (paper).

This pamphlet contains an up-to-date list of the fungi of Missouri, a host index, and an extensive bibliography.

BLACK ROCK FOREST PAPERS. *Vol. I, No. 10, The Relation Between Mycorrhizae and the Growth and Nutrient Absorption of Coniferous Seedlings in Nursery Beds*, by H. L. Mitchell, R. F. Finn and R. O. Rosendahl. *No. 11, The Effect of Soil Texture Upon the Growth of Red and Chestnut Oaks*, by Harold F. Scholz.

Black Rock Forest, Cornwall-on-the-Hudson, New York. 11 x 8½; 23; 1937 (paper).

MORPHOLOGY

A METHOD OF ANATOMY. *Descriptive and Deductive.*

By J. C. Boileau Grant. William Wood and Co., Baltimore. $6.00. 10 x 7; xx + 650; 1937.

"The book is meant to be a working instrument designed to make anatomy rational, interesting, and of direct application to the problems of medicine and surgery. The bare, dry, and unrelated facts of anatomy tend rapidly to disappear into forgetfulness. That is largely because its guiding principles are not grasped so as to capture the imagination."

Without doubt this book at least partially accomplishes this purpose. It is an admirably written text, especially insofar as it shows relationships within a particular body region. The entire volume is of regional rather than systemic organization, considering in turn the upper limb, abdomen, pelvis, lower limb, thorax, and head and neck. Special attention is given to function, and reference is often made to embryology and comparative anatomy.

The illustrations have been painstakingly made and justify Dr. Grant's pride in this feature. They consist of entirely simple line drawings showing relationships in terms of position, relative distances, and angles. However, what

has been a gain in one respect is a loss in another in that these drawings do not approach closely enough to actuality in structure. They might well be supplemented with a few plates. Whether or not the method used helps to capture the imagination, some of the facts of anatomy have been adorned and possibly made more succulent.

THE DEVELOPMENT OF THE VERTEBRATE SKULL.

By G. R. de Beer. Oxford University Press, New York; Clarendon Press, Oxford. $10.00 $9\frac{3}{4}$ x $6\frac{1}{2}$; xiv + 552 + 143 plates; 1937.

After having had the privilege of researching upon the embryological development of all the groups of vertebrates, the author is exceptionally well qualified to write a book of this type. The development of the vertebrate skull has long been studied in an attempt to delve more deeply into the phylogeny of the vertebrate types, but the results of previous studies have been so lacking in coordination and confusing in nomenclature that there has been a real need for a well organized and systematic view of the subject. This book is an attempt to meet this need.

In his introduction de Beer discusses the historical aspects of the subject, the segmentation of the head, and the nature of the tissues involved in skull formation. In the text proper he treats in a comparative manner the problems of morphology, growth, phylogenetic affinity, and experimental morphogenesis. The discussions are very detailed, but the very nature of the work requires this since, in the words of the author, " . . . in morphology, general principles are founded on matters of quite intricate detail . . . ." The volume concludes with an annotated agenda, a complete bibliography, and indices of subjects and of genera. Included also are some 140 plates of well-labeled drawings and diagrams of the skull development of the different vertebrate types.

The book is not intended to be used as a text, nor does the author expect anyone to read it from cover to cover; yet it will be extremely valuable as a reference to zoologists in general, anatomists, both comparative and human, embryologists, and palaeontologists.

THE MICROTOMIST'S VADE-MECUM (BOLLES LEE). *A Handbook of the Methods of Animal and Plant Microscopic Anatomy. Tenth Edition.*

Edited by J. Brontë Gatenby and Theophilus S. Painter with the collaboration of D. G. Catcheside, Harold J. Conn, E. S. Duthie, Helen Pixell-Goodrich, J. G. Greenfield, W. W. Kay, Reginald Ludford, K. C. Richardson, Ruby O. Stern and Raymond Whitehead. P. Blakiston's Son and Co., Philadelphia. $9.00. $8\frac{3}{4}$ x $5\frac{1}{2}$; xi + 784; 1937.

The first edition of this extremely useful guide to laboratory technique appeared 53 years ago. The author, Arthur Bolles Lee (1849–1927), just missed seeing the birth of the ninth edition which appeared in 1928 (Q. R. B., Vol. 4. No. 1). An Englishman, Lee spent most of his life in Switzerland. He is said personally to have tried out every method and technique that appeared in the earlier editions of the *Vade-Mecum*. Several chapters still stand almost as he wrote them. The present editors have had a group of ten collaborators, all connected with British institutions with the exception of H. J. Conn, of the New York Agricultural Experiment Station, Geneva, N. Y., and a number of assistants to aid them—but no longer is it possible to test out all of the various techniques. A number of changes have been made in the present edition: Two sections of the ninth edition have been dropped and a section on plant technique substituted; there are new chapters on frozen section technique and on vital staining; the chapter on staining has been recast as has the one on blood and glands; the chapter on fats has been completely rewritten; and the section on the nervous system has been revised. The index covers 43 pages. Plainly there is still life in the good old Biologist's Bible of our youth.

FUNDAMENTALS OF ANATOMY.

By Carl C Francis. C. V. Mosby Co., St. Louis. $2.75. 9 x 6; 320; 1937.

Details of structure have been omitted in this work, though the essential features of anatomy are clearly presented and excellently illustrated, most of the cuts being entirely new. Following a discussion of cells and tissues, the author continues with the structure of the organ systems and special senses. A fine chapter is that on surface anatomy. The conciseness of the material makes the book a little impractical as a text for medical students, but due to this very feature, along with a very complete glossary and index, it will serve well as an anatomical guide.

DIE LUNGENVENEN DER WIRBELTIERE. *Besonders der Säugetiere und des Menschen. Lunds Universitets Årsskrift. N. F. Avd. 2, Bd. 33, Nr. 6.*

By Gaston Backman. C. W. K. Gleerup, Lund; Otto Harrassowitz, Leipzig. Kr. 7. 10¼ x 7¾; 112; 1937 (paper).

One sees in this publication the results of a careful study of the bronchial veins. The author gives his method of preparation and a short history of work done in this field. The primates, ungulates, carnivores, and rodents occupy the greater part of the book, with briefer accounts for other mammals and the lower vertebrates. There are numerous drawings and a list of literature. According to the relationships among the trunks and branches of the veins, arteries, and bronchi, the material is summarized and divided into four general types.

PHYSIOLOGY AND PATHOLOGY

MEDICO-LEGAL ASPECTS OF THE RUXTON CASE.

By John Glaister and James C. Brash. William Wood and Co., Baltimore. $6.00. 9¾ x 7⅛; xvi + 384; 1937.

In September 1935 scattered portions of human remains were found in a stream bed in Dumfriesshire, Scotland. The introduction of this book goes briefly into the history of this now famous murder case in which a Dr. Ruxton not only murdered his wife and nursemaid, but mutilated and dissected their bodies in an attempt to make them unidentifiable. The bulk of this volume is a long and detailed description of the intricate work done by the members of the faculties of the Universities of Glasgow and Edinburgh in piecing together the remains and helping to identify the bodies.

According to the authors this volume was prepared in response to requests from officers of police forces and from members of the medical and legal professions and is "intended for those professionally interested in methods employed in the preparation of medical and other technical evidence." Among the 172 vivid illustrations some of the slightly revolting photographs of disintegrated and mutilated portions of the bodies show in the clearest manner how what is perhaps the most skilful job of biological detection on record was done. This is an exceptionally well written account with a thorough and complete summation of every conceivable angle of the investigation and of every clue that eventually helped to identify the victims. The sixteen chapters are supplemented by appendixes and there is an excellent index.

NUTRITION. *Final Report of the Mixed Committee of the League of Nations on the Relation of Nutrition to Health, Agriculture and Economic Policy.*

League of Nations. Columbia University Press, New York. $2.00. 9½ x 6¼; 327; 1937 (paper).

The League of Nations Mixed Committee on the Problem of Nutrition was organized in 1935 to make a thorough investigation of food consumption in Northern and Western Europe and in America and its relation to economic and agricultural conditions. This final report is divided into three parts, the third being a detailed presentation of the results of the investigation while the first and second are respectively a general summary of the findings and an exposition of the nutritive value of the more important foods. In the

main this investigation showed that in the last two decades the trend in food consumption has been towards a better and more diversified diet. In particular there has been a decrease in the use of such staples as wheat and a corresponding increase in the consumption of dairy products, fruits and vegetables. This progress, however, has not been sufficient to wipe out malnutrition which is still very much in evidence in a number of countries. Therefore, the Committee recommends that agriculture be allowed greater freedom to meet the changes in consumption demands and that governments should develop economic programs which will permit a more adequate satisfaction of the dietary needs of the population. As all similar publications of the League this will be found useful for the references and data which it contains.

EINFÜHRUNG IN DIE VERGLEICHENDE BIOLOGISCHE ANATOMIE DER WIRBELTIERE. *Zweiter Band. Biologische Anatomie der Ernährung.*

By Hans Böker. Gustav Fischer Verlag, Jena. RM. 13.50 (paper); RM. 15. (cloth). 10 x 6¾; xi + 258; 1937.

This is the second volume of an extremely important book. The first volume has already been noticed in this Review (Volume 11, No. 3, pp. 357–358.) This second volume deals with the biological anatomy of nutrition. There will appear in the future still another volume dealing with the anatomy of reproduction and environmental adjustments.

The author divides his discussion of the anatomical adaptations pertinent to nutrition under the following heads: 1, Searching for and recognizing food, both actively and passively; 2, Acquiring food; 3, Swallowing and breaking up food both mechanically and chemically; 4, Absorbing food, and the increase of body weight; 5, Excretion of waste products; and 6, Maintaining of the equilibrium of metabolism through respiration, hormones, and the influence of the nervous system. Under each of the sections he discusses fishes, amphibians, reptiles and birds, mammals and man. Much of the discussion is drawn from his own observations and therefore the book is more interesting and less textbookish than most discussions of comparative anatomy. Böker is a real pioneer, opening out new fields in anatomy. The only reason that English translations of the successive volumes of this masterly work are not available is because American publishers are not very bright.

THE MACHINERY OF THE BODY.

By Anton J. Carlson and Victor Johnson. University of Chicago Press, Chicago. $4.00. 9 x 6¼; xvii + 580; 1937.

This elementary text was published especially to meet the needs of students in freshmen physiology courses, but the breadth of material presented and the semi-popular style in which it is written are indicative of its value as a reference for the more advanced student of physiology, and as a guide for the energetic layman in his search for more knowledge of the human body and its functioning. The authors have refrained from the stereotyped technical discussions of theories and processes which so often characterize physiology texts, and have presented a series of thoroughly checked observations from carefully controlled experiments.

The book is organized on the organ-system plan, beginning with a discussion of the cell as the unit of structure and function and ranging through the circulatory, respiratory, digestive, excretory, nervous, and glandular systems of the body. The chapters on the glands of internal secretion and on the body defences against disease present much of the latest experimental work in physiology. A wealth of illustrative material both photographic and hand drawn is included in each chapter.

A detailed table of contents, a list of selected references, and a lengthy index complete the text.

CLINICAL PARASITOLOGY.

By Charles F. Craig and Ernest C. Faust.

Lea and Febiger, Philadelphia. $8.50. 9¼ x 5⅞; 733; 1937.

Members of the medical profession will find this an excellent aid in their practice. The volume is concerned with protozoan and metazoan parasites, presenting clinical and laboratory methods of diagnosis, type of damage produced, source and path of infection, approved therapeusis, and methods of community control. A growing knowledge of the seriousness of animal parasites in their human and economic toll points to the need for recent and accurate information, especially by physicians and health officers.

The introduction is in itself a fine essay on general parasitology. Subsequent chapters deal with the several classes of protozoa; the nematodes, flukes, and flatworms; and finally with the arthropods as parasites themselves and as vectors.

Numerous illustrations show the forms of the parasites and the physical manifestations of the diseases, with maps to show geographical distribution. The book can be used as a text or reference for students, since it contains a technical appendix regarding the collection and preparation of representative forms, as well as a lengthy bibliography, and index of subjects and of authors. The volume may be recommended for the thorough treatment which the authors have accorded their subject.

TWENTY-FIVE YEARS OF HEALTH PROGRESS. *A Study of the Mortality Experience Among the Industrial Policyholders of the Metropolitan Life Insurance Company 1911 to 1935.* *By Louis I. Dublin and Alfred J. Lotka. Metropolitan Life Insurance Co., New York.* 9¼ x 5⅞; xi + 611; 1937.

This book analyzes the mortality experience of the Industrial policy-holders of the Metropolitan Life Insurance Company from 1911 to 1935. As the authors point out, these insurance data do more than merely supplement the mortality statistics of the Bureau of the Census, since in 1911 the Death Registration Area comprised only ten states and not until 1933 was the whole United States included. In the twenty-five years there has been an average annual decline in the mortality of the Metropolitan Life Insurance Company's Industrial policyholders, standardized for color, sex and age, of 1.3 per cent of the average rate during the period. The expectation of life at birth has increased from 46.63 years in 1911–12 to 60.25 years in 1935. Besides their consideration of mortality as a whole, the authors analyze the deaths from the more important separate causes. This is a book which will repay careful study by every person interested in the health of the community.

PHENOMENON OF LOCAL TISSUE REACTIVITY *and Its Immunological, Pathological and Clinical Significance.* *By Gregory Shwartzman. Foreword by Jules Bordet. Paul B. Hoeber, Medical Book Dept. of Harper and Bros., New York.* $7.50. 9¼ x 6⅛; xxviii + 461; 1937.

As Bordet says in the foreword, after sixty years and more of intense study of the varied reactions of sensitized living tissues to bacterial toxins, no one would have believed that a remarkable phenomenon still remained to be recognized and studied, but there it was. The striking hemorrhagic lesions produced by Shwartzman must have been seen many times in the past, but their mode of production was not understood until he made his extensive studies. The phenomenon which now goes by his name appears when certain substances, usually the products elaborated by some microörganisms, enter the circulation several hours after they have been used to sensitize a certain area, usually in skin or mucosa. Curiously, the second dose of the toxin must be given intravenously, and preferably about twenty-four hours after the first dose.

The book is most thought-producing, and no one who deals with the reactions of the body to invasion by bacteria or cancerous cells can afford to miss reading it.

ASSESSMENT OF RISKS IN LIFE ASSURANCE PRACTICE. *By Jehangir J. Cursetji. (Obtainable*

from Jehangir J. Cursetji, Bombay). $7\frac{1}{4}$ x $4\frac{7}{8}$; 18; 1937 (paper).

This pamphlet contains within its few pages a very considerable amount of information which should be useful to medical examiners for life insurance companies. Dr. Cursetji shows very clearly that his long years of service together with intelligent observation have enabled him thoroughly to appraise the effects of personal and family history, general health, environment, occupation, etc. upon the insuring risk of the individual. Although he builds his work primarily upon conditions effecting life and health in India, the results of his observations apply in all climates and countries.

LIPOGENESIS IN THE ANIMAL BODY, WITH SPECIAL REFERENCE TO THE PHYSIOLOGY OF THE GOOSE. *Carnegie Institution of Washington Publication No. 489.*

By Francis G. Benedict and Robert C. Lee. Carnegie Institution of Washington, Washington, D. C. $2.00 (paper); $2.50 (cloth). 10 x $6\frac{3}{4}$; ix + 232; 1937.

The deposition of fats transformed from carbohydrates is the problem pursued in this detailed study of the physiology of the goose under normal circumstances and after starvation and over-feeding. During lipogenesis the respiratory quotient is much higher than during combustion of pure carbohydrate, and it was found that the quotient was high after surfeit feeding, an indication that carbohydrate was being deposited.

GENERAL HYGIENE AND PREVENTIVE MEDICINE. *A Text-Book for College Students, Medical Students, Nurses, Public Health Workers and Social Workers.*

By John Weinzirl. Edited by Adolph Weinzirl. Lea and Febiger, Philadelphia. $4.00 $9\frac{1}{4}$ x $5\frac{7}{8}$; 424; 1937.

The author of this book, a bacteriologist interested in public health, has approached his subject in what he feels is a new way, stressing epidemiology and methods of prevention of disease. Statements as to treatment are brief, and often only long enough to show the student how little can be done in a curative way once the disease has attacked. After discussing methods of immunization and the use of specifics such as medicines and vitamins, the writer takes up the control of carriers and of groups in the community, and of the several sanitary, physical, personal, and social environments.

HANDBUCH DER BIOLOGISCHEN ARBEITSMETHODEN. *Lieferung 464. Abt. V. Methoden zum Studium der Funktionen der einzelnen Organe des tierischen Organismus, Teil 7, Heft 13 (Schluss). Gehörsinn, Hautsinne, Kraftsinn (Muskelsinne), Geschmack- und Geruchsinn, Statischer Sinn, Stimme und Sprache.* Containing following articles: *Neue Verfahren zur Erforschung der Leistungen des Druck-, Temperatur-, Schmerz- und Kraftsinnes (Schluss)*, by Emil von Skramlik; *Verfahren zur Prüfung der haptischen Leistungen*, by Emil von Skramlik; *Methoden zur Messung von Schall und Erschütterungen*, by Hermann Reiher.

Urban und Schwarzenberg, Berlin. RM. 13.50. 10 x 7; 236; 1937 (paper).

The first paper in this volume is the continuation and conclusion of a paper on the function of perceptors of pressure, temperature, pain, and kinesthesia published in *Lieferung* 463, and already noticed in the Q. R. B. (Vol. 12, p. 492). There is also an article on a method for testing tactile function, and a new method described for testing the range of perception in man of sound vibrations—those that can be borne with ease as well as those that are harmful or painful.

MATERNAL DEATHS—THE WAYS TO PREVENTION.

By Iago Galdston. Commonwealth Fund, New York; Oxford University Press, London. 75 cents (cloth); 50 cents (paper); 25 per cent discount on lots of 10 or more. $8\frac{1}{4}$ x $5\frac{1}{2}$; [10] + 115; 1937.

This booklet written for the general public is based essentially on the facts brought out in the survey of maternal mortality conducted in New York City a few years ago. In a style both limpid and concise Dr. Galdston considers the

practical means of reducing puerperal mortality. He concludes that the problem should be attacked by educating the general public and by developing better medical standards. In an appendix is contained an outline of the community organization of obstetrical services in the hospitals of Cleveland, Ohio.

INTRODUCTION TO PHYSIOLOGICAL OPTICS. *By James P. C. Southall. Oxford University Press, New York and London.* $5.50. 9¼ x 6; x + 426 + 3 plates; 1937.

This is a simple and concise exposition of the fundamental facts and theories regarding the optical system and the physiology of the eye. The author describes the anatomy and kinematics of the eye, optical defects and means of correction, binocular vision, color vision and colorimetry and certain problems of temporal and spatial reactions of the organ of vision. The intent of the book is to give a clear understanding of the subject to undergraduate students and laymen, and the author has certainly achieved his objective.

THE FUNCTION OF THE SUB-OCCIPITAL MUSCLES. *The Key to Posture, Use and Functioning.*

By A. Murdoch. (Obtainable from A. Murdoch, Bexhill-on-Sea, Sussex, London). 8½ x 5½; 19; 1937 (paper).

Mr. Murdock believes that the seat of good posture lies in the control of the "Cranial Globe" through the action of the sub-occipital muscles. He attempts to provide an anatomical explanation for Alexander's theory of "The Primary Control," noticed in this Review several years ago (Vol. 8, p. 241). The brochure suffers from a lack of illustrative material.

BIOCHEMISTRY

THE BIOCHEMISTRY OF CELLULOSE, THE POLYURONIDES, LIGNIN, ETC.

By A. G. Norman. Oxford University Press, New York; Clarendon Press, Oxford. $5.00. 9¼ x 6¼; viii + 232; 1937.

In both industry and agriculture a large part of the raw material in the form of plant derivatives has been going to waste. With further advancement in the biochemistry of the complex substances that make up cell walls, it is probable that considerable savings could be accomplished through new and useful outlets for these materials. The author describes to the full extent of present knowledge, the properties, composition and structure, preparation, and biological decomposition of cellulose, the hemicelluloses, pectins, gums, mucilages, and lignin. He then critically surveys the theories of cell-wall metabolism. Bacterial and fungal polysaccharides are also considered. This book will be a standard reference for anyone interested in plant derivatives. It is indexed by authors and subjects.

PERSPECTIVES IN BIOCHEMISTRY. *Thirty-one Essays presented to Sir Frederick Gowland Hopkins by past and present members of his Laboratory.*

Edited by Joseph Needham and David E. Green. University Press, Cambridge; The Macmillan Company, New York. $4.75. 8½ x 5½; x + 361 + 6 plates; 1937.

An interesting and stimulating volume. The aim of the writers (there were 31 contributors) has been

> to indicate the most promising lines of advance in the various fields which they survey, and while maintaining a due standard of criticism, to speculate a little on the likely paths of future thought and discovery. It will be seen that in accordance with the wide interests of the founder and head of the Cambridge Biochemical Laboratory, the essays touch on many aspects of the science of life—physiology and zoology, embryology and genetics, medicine, bacteriology, and nutrition—with all its great bearing on human welfare.

It is only possible in these columns to mention a few of the subjects discussed and the authors—Proteins and cell-organization by R. A. Peters; Chemical aspects of morphogenetic fields by Joseph Needham; The chemical regulation of insect growth by V. B. Wigglesworth; The biological function of magnesium by Ida Smedley Maclean; Calcium and blood

coagulation by John Mellanby; and Vitamin C and infection by Leslie J. Harris.

CHEMISTRY OF THE BRAIN.

By Irvine H. Page. Charles C Thomas, Springfield, Ill. $7.50. 10 x 6¾; xvii + 444; 1937.

This book was designed to bring together all the available data on the chemical constitution of the brain and the relation between chemical changes and certain pathologic processes in man especially. Following a brief historical note on the subject, the author proceeds to consider in some detail sterols, phosphatides, cerebrosides, carbohydrates, enzymes and vitamins. He discusses also the metabolism of the brain and its measurement; and in particular the effects of variation in water, fatty acid and nitrogenous metabolism. In addition, there are chapters on electrolytes and gases and the chemical changes associated with the growth of the brain. J. H. Quastel contributes a chapter on oxidations in the brain. In the treatment of each subject the author describes the chemical structures, and reviews the results of animal experimentations and of observations on human material. He does not limit himself to the brain only but discusses other organs as well. It is a thorough piece of work and the literature has been carefully selected.

VITAMIN CONTENT OF FOODS. *A Summary of the Chemistry of Vitamins, Units of Measurement, Quantitative Aspects in Human Nutrition and Occurrence in Foods. U. S. Department of Agriculture. Miscellaneous Publication No. 275.*

By Esther P. Daniel and Hazel E. Munsell. Government Printing Office, Washington. 15 cents. 10 x 6¾; 175; 1937 (paper).

At first glance this discussion of the vitamin content of foods seems far too technical for the layman. Nevertheless a little study shows that much that is of value to the housewife (one of whose chief duties is to have a knowledge of food values) can be gleaned from these pages. With over 100 pages of tabular matter and a bibliography of 771 titles, a useful reference work has been provided for both investigator and layman—and all for the very small sum of 15 cents.

ALLGEMEINE PHOTOCHEMIE. *Ein Hand- und Lehrbuch für Studium und Forschung für Mediziner, Biologen, Agrikultur-Chemiker, Botaniker, usw. Zweite, umgearbeitete und erweiterte Auflage.*

By J. Plotnikow. Walter de Gruyter and Co., Berlin and Leipzig. RM. 28.50. 9½ x 6½; viii + 909; 1936 (paper).

This second edition is a considerable enlargement over the first which appeared in 1910. There are new chapters on fluorescence, phosphorescence, light reactions, animal luminescence, the effects of ultra-red, ultra-violet and Röntgen rays. There is also a discussion of the place of photochemistry in other sciences. The book is an elaborate and thorough treatise on the subject, already a standard classic in the field.

TRAITÉ DE CHIMIE ORGANIQUE. *Tome V. Les Métaux en Chimie Organique. Alcools dans Toutes les Séries. Formation des Alcools par Voie Biochimique. Synthèse du Méthanol. Industrie de l'Alcoolé Thylique. Éthers-Oxydes. Éthers-Sels des Acides Minéraux.*

By P. Baud, Ch. Courtot, Cl. Fromageot, J. Lichtenberger, Ch. Prévost, J. B. Senderens. Published under the direction of V. Grignard, G. Dupont, R. Locquin and Paul Baud. Masson et Cie, Paris. 310 francs. 10 x 6½; xix + 1047; 1937.

As in earlier volumes of this comprehensive treatise, noticed from time to time in these columns, this weighty tome contains chapters by authorities in specialized sub-division of organic chemistry as indicated in the title. There are indexes of authors and substances, and a bibliography, up to January 1934, on physical constants of ethers of the mineral acids and monoalcohols. The *Traité* is a work of first rank importance.

SEX

GENITAL ABNORMALITIES, HERMAPHRODITISM AND RELATED ADRENAL DISEASES. *By Hugh H. Young. Drawings by William P. Didusch. Williams and Wilkins Co., Baltimore.* $10.00. 10 x 7; xli + 649; 1937.

The subject of hermaphroditism and of genital abnormalities in general has very rarely received such a comprehensive treatment as in this volume. In the first chapter Young relates the myth of Hermaphrodites and the manifestations of art and literature based upon it. In the next two chapters, the development of hermaphroditism and the several varieties of hermaphrodites are described. The following chapters contain detailed case histories of pseudo-hermaphrodites and of the one case of true hermaphroditism seen by the author. In relation to this, there are also summarized the other 19 authentic cases reported in the literature. The remaining chapters include a discussion of, and case reports illustrating, the adreno-genital syndrome, ovarian tumors, hypergenitalism, hypogenitalism, gynecomastia, hypospadias, epispadias, cryptorchidism and the various other abnormalities of the genital system. The case reports contain not only the anamnesis and the results of the physical examination but whenever possible the histologic and pathologic findings in addition to a minute and profusely illustrated description of the surgical techniques used.

This rapid survey of its contents is sufficient to indicate that this book is of interest not only to physicians and surgeons but to all students of biology. It is well written and represents an important contribution to human biology as well as to surgery. Praise should also be given the artist and the publishers, whose efforts have made this a beautiful book.

CLINICAL CONTRACEPTION. *Second Edition. By Gladys M. Cox. Introduction by Lord Horder of Ashford. William Heinemann (Medical Books), London.* 7s. 6d. net. 8½ x 5½; ix + 196; 1937.

PRACTICAL BIRTH CONTROL. *A Guide to Medically Approved Methods for the Married. By Rita Irwin and Clementina Paolone. Robert M. McBride and Co., New York.* $1.75 7½ x 5¼; xxiii + 172; 1937

CALENDAR LOVE. *The Truth About Birth Control. By Herman Goodman. Hermes Publishing Co., New York.* 50 cents. 8 x 5½; 55; 1937 (paper).

The first two of these books outline the approved methods of contraception, their advantages and objections both from the effective and aesthetic points of view. Both are clearly written, straightforward, and adequately adapted to their respective purposes. Dr. Cox's book, written for physicians, contains also some statistical material regarding the effectiveness of contraceptive practice as obtained from clinics in England, a list of manufacturers of tested appliances, and illustrations. *Practical Birth Control* is intended for lay instruction.

Calendar Love, discussing other methods of birth control besides the use of the "safe-period," is stated in the preface to be "a discussion for adults old enough to recognize that storks don't bring babies, and that passionate kissing doesn't cause pregnancy." We make objection to that statement and suggest the substitution of the words "not intelligent enough" for "old enough." A sample sentence is: "If a man were supposed to wear one [a pessary], he never would."

WHAT'S BEHIND DIVORCE *or the Key to Happier Marriages. Based on an Analysis of Over One Thousand One Hundred Actual Divorces—Over Two Thousand Unhappy But Undivorced Marriages—Close to Twenty Thousand Years of Married Life. By John A. Hadaller. Obtainable from Major John A. Hadaller, San Bernardino, Cal.* 75 cents. 7¾ x 5½; 82; 1937 (paper).

The author, a Major and a member of the California State Bar Association, here offers a solution to the divorce problem so simple that it should solve the difficulty once and for all—provided, of course, that human nature changes. All hinges on the

interval in days between the birth dates between the prospective partners. About half the combinations on an 180 degree arc (approximately half a year) are rough on marriage and the other half are good in the absence of unfavorable elements such as drunkenness, troublesome fathers-in-law, or "general cussedness." On page 80 we read:

> Being a lawyer and a student of social matters, I know how difficult it is to change the established order of things. But I have faith. Louis Pasteur . . . finally forced the scientific world to accept what his patience and study had proved to him to be true about bacterial diseases. . . . If we are willing to make laws about vaccination for disease, I feel confident that we will also agree to make laws about this bacillus matrimonii. All we need is an interested body to espouse the cause and bring it forcefully to the attention of the legislatures.

We nominate the Major for a Nobel Peace Prize, or failing that a leather medal, for this great contribution.

COMING INTO BEING AMONG THE AUSTRALIAN ABORIGINES. *A Study of the Procreative Beliefs of the Native Tribes of Australia.*

By M. F. Ashley-Montagu. Foreword by B. Malinowski. George Routledge and Sons, London. 21s. net. 10 x 6⅛; xxxvi + 362 + 5 plates; 1937.

Since Spencer and Gillen's report in 1899 ethnologists have debated whether the purported ignorance of the Australian aborigines regarding the relation between coitus and pregnancy is real or only apparent. In this somewhat massive book the author reexamines all the pertinent accounts dealing with the beliefs of the Arunta, in particular, regarding the causes of reproduction. From his analysis he is led to conclude that the Australian has no conception of the connection between coitus and pregnancy, and therefore paternity for him has no physiologic significance. Moreover, Ashley-Montagu contends, that in maintaining such a belief the Australian is consistent with his experience and with the structure of his social and religious ideas. In order to arrive at such a definitive and unqualified conclusion the author has had to generalize from evidence that at best is rather weak. This will undoubtedly lay him open to severe criticism. Nevertheless, it cannot be denied that the author has done a useful service in ordering the literature on the subject. The student will find the references handy, although an awkward and repetitious style in addition to some minor typographical errors make this book rather heavy reading. Malinowski's foreword is laudatory.

RHYTHMIC DIURNAL VARIATIONS IN THE OESTROUS PHENOMENA OF THE RAT AND THEIR SUSCEPTIBILITY TO LIGHT AND DARK. *Det Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser. XIII, 7.*

By Axel M. Hemmingsen and Niels B. Krarup. Levin and Munksgaard, Copenhagen. Kr. 3.00. 9½ x 6; 61 + 4 folding charts; 1937 (paper).

THE PRODUCTION OF MATING INSTINCTS IN THE RAT WITH CHEMICALLY WELL-DEFINED OESTROGENIC COMPOUNDS. *Det Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser. XIII, 8.*

By Axel M. Hemmingsen and Niels B. Krarup. Levin and Munksgaard, Copenhagen. Kr. .50. 9½ x 6; 9; 1937 (paper).

The first of these studies is concerned with the study of the diurnal rhythm of biological processes with stress on the daily periodicity of oestrous phenomena in the rat. Three groups of oestrous phenomena are studied: spontaneous muscular activity, mating instincts, and epithelial changes in vaginal smears of the rat under the normal day-night alternations. All three phenomena are found to be confined to certain hours of the day-night rhythm, heat and activity being greatest in the dark. The three phenomena can be shifted twelve hours by an establishment of an artificial day-night rhythm. The authors describe a convenient technique of artificial illumination.

The second study describes the results on spayed female rats with oestrogenic compounds under reversed conditions of day and night. In addition to positive vaginal smear changes, reliable mating instincts of high degree, and enhanced spontaneous muscular contractions were

produced. The question of specificity of the female sex hormones is briefly considered.

LOVE, MARRIAGE AND DIVORCE.

By Macpherson Lawrie. Methuen and Co., London. 5s. net. $7\frac{3}{8}$ x $4\frac{7}{8}$; [8] + 198; 1937.

The two imaginary characters, Antony, aged forty-two, and Cathrine, aged thirty, are divorced after six years of married life. And why? Antony was weaned too early; was fed on processed foods that were not good for his system; had resort to medicinal correctives; developed badly adjusted social relationships with an inferiority complex as the consequence; was not quite all there so far as sexual attitudes were concerned, and so on. Cathrine was weaned and nurtured properly, but was thoroughly spoiled in the course of her up-bringing, and so on once more. If solemn head shakings over the undesirability of processed foods, the unnaturalness of this, and the inadequacies of that constitute scientific arguments, then this book is sane, discriminating, and full of good sense.

BIOMETRY

AN INTRODUCTION TO THE THEORY OF STATISTICS. *Eleventh Edition, Revised Throughout and Re-Set.*

By G. Udny Yule and M. G. Kendall. Charles Griffin and Co., London. 21s. net. $8\frac{3}{4}$ x 6; xiii + 570 + 4 folding plates; 1937.

For a quarter of a century Yule's *Introduction* has been one of the best of the statistical textbooks. In the skill with which statistical methods have been presented for students with no greater knowledge of mathematics than algebra and the elements of coördinate geometry, and above all in its emphasis on pitfalls of erroneous interpretation into which the beginner—and often times the more advanced statistician—may be led it has been a model of what an introduction to statistics should be.

In successive editions new developments in the field of statistical methodology have been treated in supplements. With the present edition, however, it was decided that the time had come for a general revision, which has been made largely by Mr. Kendall. Old friends of the book will still find most of the material appearing in earlier editions, but several new chapters have been added on sampling, including an introduction to small sample methods. Other additions deal with moments, measures of skewness and kurtosis, simple curve fitting by the method of least squares, and interpolation and graduation. Another new feature is an appendix of tables of the area and ordinates of the normal curve, of the χ^2 integral for one degree of freedom, of Student's t distribution, and of Fisher's z distribution, and a nomogram of χ^2.

In concluding the chapter on interpolation and graduation Mr. Yule reminds the student that "*interpolare* means not only 'to polish up' (*polire*, to polish)—so that graduation is really the implication of the word—but hence 'to corrupt, to falsify.' It will do him no harm to bear this etymological meaning in mind, and keep a look-out accordingly." This caution may well apply not only to interpolation but to the whole practice of statistics.

THE METHODS OF STATISTICS. *An Introduction Mainly for Experimentalists. Second Edition Revised and Enlarged.*

By L. H. C. Tippett. Williams and Norgate, London. 15s. net. $8\frac{1}{2}$ x $5\frac{1}{2}$; 280; 1937.

This edition of Tippett's book, with but few minor exceptions, follows very closely the plan of the earlier one. The first three chapters have been revised and rewritten in such a manner as to lay a more thorough and substantial foundation upon which to develop succeeding theories and discussions. As in the former edition, emphasis has been placed upon the elementary concepts of the various theories of statistics, and where it has been possible to give proofs the more typical ones have been presented The logic of organization and presentation, and the clarity of style are characteristics which tend

to make the book popular among those workers whose mathematical backgrounds have been slighted. As in the former edition, numerous drawings, charts, tables and formulae are used as illustrative material. The list of bibliographic references and the index have been revised and enlarged.

PSYCHOLOGY AND BEHAVIOR

SCIENCE AND MUSIC.

By Sir James Jeans. The Macmillan Co., New York, University Press, Cambridge. $2.75. 8½ x 5⅝; x + 258 + 10 plates; 1937.

In some of the English universities it is the custom for the chief of the department of music to be also a member of the staff of the department of astronomy. The origin of the tradition is unknown, but since it is the tradition we need not be surprised when the best known English astronomer writes a book dealing with the scientific aspects of music.

Jeans is blest with clarity of expression surpassing that of most writers on any subject, and just as his astronomical writings are more easily comprehended than those of most of his contemporaries, his book on music makes better reading than the older works of Pole and Taylor whom he seems likely to supplant. He has used the excellent if old idea of blowing smoke through organ pipes while playing that instrument in order to make visible the aerial whirlpools that form where the jet impinges on the lip, and the resulting photographs are remarkable. The reader is likely to wish that Jeans had had a set of orchestral wind instruments of glass that might have been photographed under similar conditions. There is also a discussion of the sounds produced by the wind when it whistles in a chimney or in the rigging of a sail boat. The designer of aeroplanes would profit by reading this chapter, for he might learn more about what happens when the edge of a plane is turned into the wind. The discussion and comparison of the four systems of temperament is well handled and worth attentive study. There are also chapters on the acoustics of concert halls, and the anatomy and function of the human ear, and an index of six pages.

Of course, those who enjoy looking for defects will not be disappointed. Even Homer sometimes nods. Among these is the tendency to use well established terms with new and unfamiliar meanings. The author tells us that tunning forks have no natural harmonics (?) but that artificial harmonics may be produced by striking the fork on the end instead of on the side, and that the notes so produced are called clang-tones. Now the term clang-tone was originally used by Tyndall to designate a fundamental sounding with its natural harmonics—the equivalent of the German *Klangfarbe*. And the term artificial harmonic has been used in violin playing to denote merely a natural harmonic on a stopped string. Also Jeans tells us that the characteristic tone of the clarinet is due to the absence of the even partials, and that this is the result of the cylindrical bore of the instrument. But he does not explain why these same even partials are present in the synthetic clarinet tone of the Hammond organ, and also in that of the trombone, which also has a cylindrical bore. And speaking of bores, the author also tells us that flutes have tapering bores with the narrow end at the embouchure, but both Cecil Forsyth and Sir George Grove tell us that flutes are generally cylindrical, but that when a tapering bore is resorted to the broad end is always at the embouchure. One does not like to question Jean's statements, but one does hope that this book will receive the attention it deserves and that the author will be encouraged to prepare a new edition in which some of these difficulties will be elucidated.

OBJECTIVE ANALYSIS OF MUSICAL PERFORMANCE. *University of Iowa Studies. Studies in the Psychology of Music, Volume IV.*

Edited by Carl E. Seashore. University Press, Iowa City. $2.00 (paper); $2.50 (bound). 9¼ x 6; 379; 1936.

The science to which has been given the somewhat awkward but readily comprehended term of musicology is, like Gaul,

divided into three parts. First, there is the physical science of acoustics, with which the names of Mersenne, Chladni, Tyndall, and Helmholtz are indelibly associated. Second, there is the science of musical composition that reminds us of Fuchs, Marpurg, Cherubini, and Berlioz. And last there is the science of aesthetics which we owe chiefly to Herbart, Marx, Gurney, and Hanslick.

Almost without exception these authorities wrote and thought as if they lived in water-tight bulkheads, and the healthy growth of musical criticism has been greatly hampered in consequence. For too long it has been under the domination of the shallower minds of such writers as Ambros and Perry. Even such a really great aesthetician as Bosanquet is hopelessly at sea when he discusses music, and Lessing wisely ignored this art altogether.

Within recent years the tide has turned. Seashore and his satellites at the University of Iowa have undertaken a psychological examination of musical compositions and their interpretation that seems likely to go far toward establishing a scientific foundation on which may be erected an intelligent aesthetic in the future. The present work is the fourth volume in a series devoted to this end. It is not simple reading but demands all the mental concentration that the reader can muster. But he who reads these essays will be amply repaid for his trouble, whether he be composer, performer, or critic.

Perhaps the most striking essay in the collection is one devoted to the analysis of violin playing relative to the Pythagorean, equal, and just systems of temperament. Almost without exception the critics have dogmatically stated that violinists who play unaccompanied instinctively play in just temperament, yet the outcome of this investigation is that in every instance the standard deviation in pitch was least when measured from the Pythagorean intonation, and greatest when measured from the justly tempered intervals. It would have been interesting had the investigator distinguished between essential and inessential dissonances, for it is conceivable that the deviations might have been different in the two cases. Such an investigation is badly needed.

There is one typographical error—one chapter heading refers to the first movement of one of the Beethoven piano sonatas, but an examination of the score shows that the last movement was intended. But details like this do not detract much from the value of the work, which is really deserving of a great deal of commendation.

SLEEP CHARACTERISTICS. *How They Vary and React to Changing Conditions in the Group and the Individual.*

By N. Kleitman, F. J. Mullin, N. R. Cooperman and S. Titelbaum. University of Chicago Press, Chicago. $1.00. 8½ x 6; vi + 87; 1937.

The subjects were selected from the laboratory personnel—students, instructors, employees, and a few outsiders. Data were collected on the amount of motility during sleep, number of hours slept, continuity of sleep, dreaming, spontaneity of awakening, etc. The effects of climatic conditions, food intake, and the subjective condition of the person at the time of retiring were all studied. Numerous tables have been included in the text. The material has been analyzed statistically, with special emphasis on variance analysis.

EDUCATIONAL, PSYCHOLOGICAL AND PERSONALITY TESTS OF 1936. *Including a Bibliography and Book Review Digest of Measurement Books and Monographs of 1933–36.*

By Oscar K. Buros. School of Education, Rutgers University, New Brunswick, N. J. 75 cents. 9 x 6; 141; 1937 (paper).

This bulletin is a non-cumulated number including only tests published in 1936 and tests not included in earlier bibliographies, 1933–35. Practically all 1936 pencil-and-paper tests published as separates in the United States and the British Empire, and many non-pencil-and-paper tests are included. The contents include a bibliography of tests, a bibliography of

books with review excerpts, a publisher's directory and index, a periodical directory and index, and an index by titles and by authors.

FOOD-TOKENS AS INCENTIVES FOR LEARNING BY CHIMPANZEES. *Comparative Psychology Monographs, Volume 14, Number 5. Serial Number 71.*

By John T. Cowles. Johns Hopkins Press, Baltimore. $1.75. 10 x 5⅞; 96; 1937 (paper).

Because human activity is concerned neither directly nor entirely with the need for food, animal experiments involving immediate food reward may not be comparable. This experiment was to determine the efficacy of substitute rewards which lead to the acquisition of new habits. A number of position and visual discrimination patterns from simple to complex were used, and in each case the responses to direct food, food-token, and non-food-token rewards were compared. The results are summarized and discussed.

THE INTELLIGENCE OF ANIMALS.

By G. C. Grindley. Methuen and Co., London. 2s. 6d. net. 6⅝ x 4¼; vii + 70: 1937.

A short review of the experimental work that has been done on conditioned reflexes, maze learning, and of various other experimental techniques that have been devised for testing an animal's ability to reason. It is made abundantly clear that very little is known about animal intelligence.

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

THE ADVANCING FRONT OF SCIENCE.

By George W. Gray. Whittlesey House, McGraw-Hill Book Co., New York and London. $3.00. 9 x 6; xiii + 364; 1937.

Here is an attempt to cover the entire domain of modern scientific activity within the covers of a single volume. Anyone who wishes to read it intelligently had better give up at the outset all idea of doing anything else at all until he is finished, for it will require all of his attention. In the preface the author extends thanks to about fifty collaborators, to consult all of whom constituted no mean task in itself.

In the opening chapter we are informed that the three fundamental problems awaiting solution at the hands of science are (1) The relativistic formulation of the quantum theory, (2) The nature of the atomic nucleus, (3) The nature of life. Any one of these seems like a pretty big order, but the author has courageously tackled them all, not of course with the idea of finding the solutions, but to show what has already been accomplished, and what is now being done in this direction. There are nine finely printed pages of index.

At the beginning of the century much of the traditional science of the past suddenly collapsed. The measurements of the velocity of light by Fizeau, and by Michaelson and Morley initiated a revolution in physics, the discovery of radioactivity did the same in chemistry, as did the rediscovery of Mendel's work and the genetic experimentation that followed it in biology. The reader will find the latest phases of all of these discussed in this remarkable production.

Unfortunately, there are no illustrations. The reading matter is a little heavy and some good illustrations would have been very helpful enabling the reader to follow the writer's thought. But nevertheless it is a fine job of the highest type of popularization.

THE TYRANNY OF WORDS.

By Stuart Chase. Harcourt, Brace and Co., New York. $2.50. 5½ x 8; xiv + 396; 1937.

The wholly laudable intent of this book is to make the general public more aware than it now is about the importance of semantics for the business of living. There appears to be little doubt that if people generally paid more attention than they do to the meanings of words they glibly use our communal troubles might be diminished. Almost certainly the mass of

humanity would be less easily hoodwinked by Pied Pipers in high places with seductive radio voices.

Particularly Chase has tried, with on the whole praiseworthy success, to translate the high points of Korzybski's important but difficult treatise *Science and Sanity* into less forbidding language than that in which its gifted but not exactly pellucid author originally crouched them. The result is a book that every graduate student in science, and particularly in biology, will greatly profit by reading. Oldsters might profit too, but realistically not much can be hoped for in that direction, so compelling is the protoplasmic hysteresis that increases with advancing age. But there is another reason apart from its main objective that will make this book entertaining and useful to biologists. It contains a great many shrewd, amusing, and sound observations about the behavior of the author's tomcat Hobie Baker. Indeed one is compelled to wonder whether Mr. Chase might not have better fulfilled the higher cosmic purpose if he had devoted his life to the serious scientific study of the behavior of the lower vertebrates instead of just being a writer about human social and economic oddities.

The book has a brief but well selected bibliography, and an excellent index.